

BBC



**ROBOTS GET CONSCIOUS**  
Should we build moral machines?

**THE LARGE HADRON COLLIDER**

The world's biggest experiment explained

What it will find and why it matters

# FOCUS

## SCIENCE AND TECHNOLOGY

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ISSUE 279 / APRIL 2015 / £4.25

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**UNIVERSE  
NEXT DOOR**  
...where time runs backwards

### QUEST FOR ETERNAL LIFE

New breakthrough reverses ageing in human cells

### ORIGIN OF THE SOLAR SYSTEM

Will a NASA spacecraft uncover the answers this month?

### Q&A

- Why do we trust some people but not others?
- Is there life deep inside the Earth?
- Can radar see through walls?

### ALTERNATIVE MEDICINE THAT WORKS

Meet the man who tested them all



9 770966 427135



04 >







# MAN OF TODAY

GERARD BUTLER FOR BOSS BOTTLED



**BOSS**  
HUGO BOSS

#MANOFTODAY





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# WELCOME



TWO YEARS AGO I stood in a concrete tunnel 100m underground in France, marvelling at a very long pipe. The pipe looked pretty ordinary, but it carries something extraordinary – subatomic particles travelling at near light-speed. It is, of course, the Large Hadron Collider and it was down for maintenance during my visit. This month, after extensive upgrades, it will be switched on once more, so we've put together a special report to celebrate. *Focus* commissioning editor Jason Goodyer (who visited with

me) sets the scene on p86, while physicist Jon Butterworth explains what he and his colleagues are hoping it will find this time round.

This month is also special for astronomy. A space probe called Dawn reaches the dwarf planet Ceres, hoping to shed more light on the Solar System's icy bodies (see p48). And *Stargazing Live* returns to BBC TV, coinciding with a total eclipse of the Sun on 20 March.

This issue we also tackle one of the biggest mysteries of all – time, and the place it might run backwards (p40). Elsewhere we find out if we can rid the oceans of all the plastic we've put there (p60) and whether we'd really want a Hollywood-style conscious robot (p114). Enjoy the issue!

Graham

Graham Southorn, Editor

**PS Don't miss our May issue, on sale 2 April 2015**



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THIS MONTH WE...



**...talked to psychologist Susan Pinker** about the benefits of catching up face-to-face rather than via online communication. Listen to her thoughts on the *Focus* podcast.

**...got some advice from Edzard Ernst**, who made a career out of investigating alternative medicine. We find out the surprising truth about which alternative therapies work and which are snake oil (p58).



**...tried out the latest tough headphones** by sticking them under the shower, treading on them and generally bashing them about. Find out which ones we liked best on p83.

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## APPEARING IN THIS ISSUE...



### Hayley Birch

Science writer Hayley is co-author of *The Big Questions In Science*.

On p60, she takes a closer look at the plastic floating in our oceans and finds out what's lurking beneath the surface.



### Jon Butterworth

Jon is a physics professor at University College London and

works on CERN's Atlas experiment. On p86 he tells us what scientists hope to find when the LHC is switched back on.



### Marcus Chown

Award-winning science writer and author Marcus talks

about a new theory of time that could solve some of the biggest problems in physics. Turn to p40 to discover more.



### Colin Stuart

Astronomer Colin is also co-author of *The Big Questions In Science*.

On p48, he finds out what the Dawn mission to Ceres will teach us about the Solar System's origins.



**WANT TO SUBSCRIBE?**

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**SUBSCRIBER BONUS**

On p36, **Prof Jennifer Clack** explains how ancient animals first hauled themselves onto dry land

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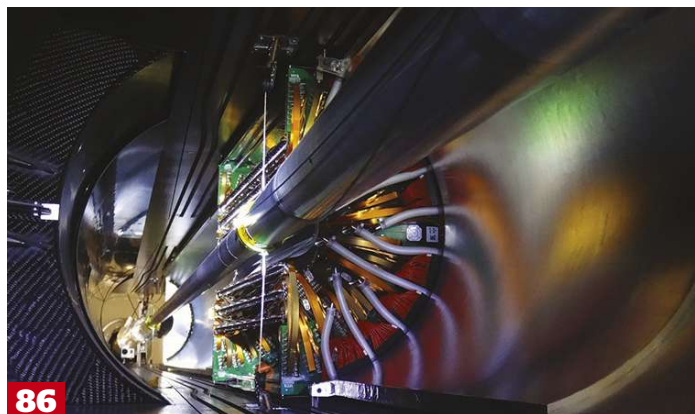
The man who's spent his career investigating alternative medicine

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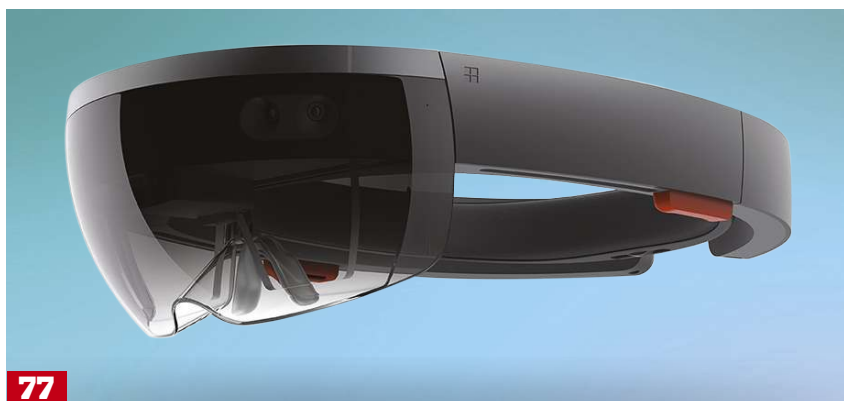
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Awe-inspiring images from the world of science

# MegaPixel







## Flying high

RESEMBLING A CLUTCH of giant eggs, Britain's latest helium-filled airship, Airlander 10, sits in a cavernous hangar at RAF Cardington. Despite being the world's longest aircraft at 92m (302ft) in length, the vessel is surprisingly agile. It is able to take off and land from any flat surface, including water, sand and ice, and can carry loads exceeding 10 tonnes. It can attain speeds of 110-130km/h (68-81mph).

"It flies and floats like an airship, its unique hull shape creates aerodynamic lift like an aeroplane, and its engines can rotate and push air out at any angle, allowing it to hover and be controlled like a helicopter," explains Chris Daniels at Hybrid Air Vehicles, the company responsible for its design. "This makes it an exceptionally efficient and versatile aircraft, with endurance measured in weeks, rather than days."

It could potentially be used for search-and-rescue missions, luxury cruises, or carrying freight to remote locations such as oil rigs, the company says. Test flights are scheduled for later this year.

PHOTO: GETTY





**MegaPixel**

## Dunes and lagoons

LAGOONS FILL THE troughs between white sand dunes in the Lençóis Maranhenses National Park situated on Brazil's northeast coastline. Thanks to the landscape's resemblance to laundry hanging on a clothes line, the park's name translates to 'Bedsheets of Maranhão'.

The dunes can reach an incredible 40m in height. They are formed when sand carried by rivers to the Atlantic is driven back inland by powerful winds.

"In the wet season, rains collect in the lower troughs

of the dunes and does not percolate and drain away into the ground because there is an impermeable rock formation under the dunes," explains Hull University's Prof Daniel Parsons.

Although these lagoons are temporary, they still contain life. During the rainier months, fish and insects reach the lagoons via interconnecting rivers. This ecosystem doesn't last for long, as the lagoons evaporate when temperatures rise in October.

PHOTO: GETTY









**MegaPixel**

## Psychedelic stinger

THIS TANGLE OF pastel-hued coils belongs to a Portuguese man-of-war. Despite resembling a jellyfish, it is actually a compound organism called a siphonophore. A gas-filled sac, a pneumatophore, floats on the ocean's surface. Three types of polyp create a drifting veil of tentacles that stretches for up to 50m.

"Each type of polyp is so specialised; they can't survive independently," explains marine biologist and BBC radio presenter Helen Scales. "Hanging down are tentacles made from polyps with stinging cells that capture prey, dactylozooids; feeding polyps that secrete digestive juices, gastrozooids; and finally gonozooids that are in charge of reproduction."

The name comes from its supposed resemblance to an 18th-Century warship. They can be found in the Pacific, Indian and Atlantic Oceans.

"The sting is extremely painful," says Scales. "They can cause skin lacerations, convulsions and problems with breathing. Occasionally they're lethal. Their long tentacles can break off and retain their sting for days."

PHOTO: AARON ANSAROV



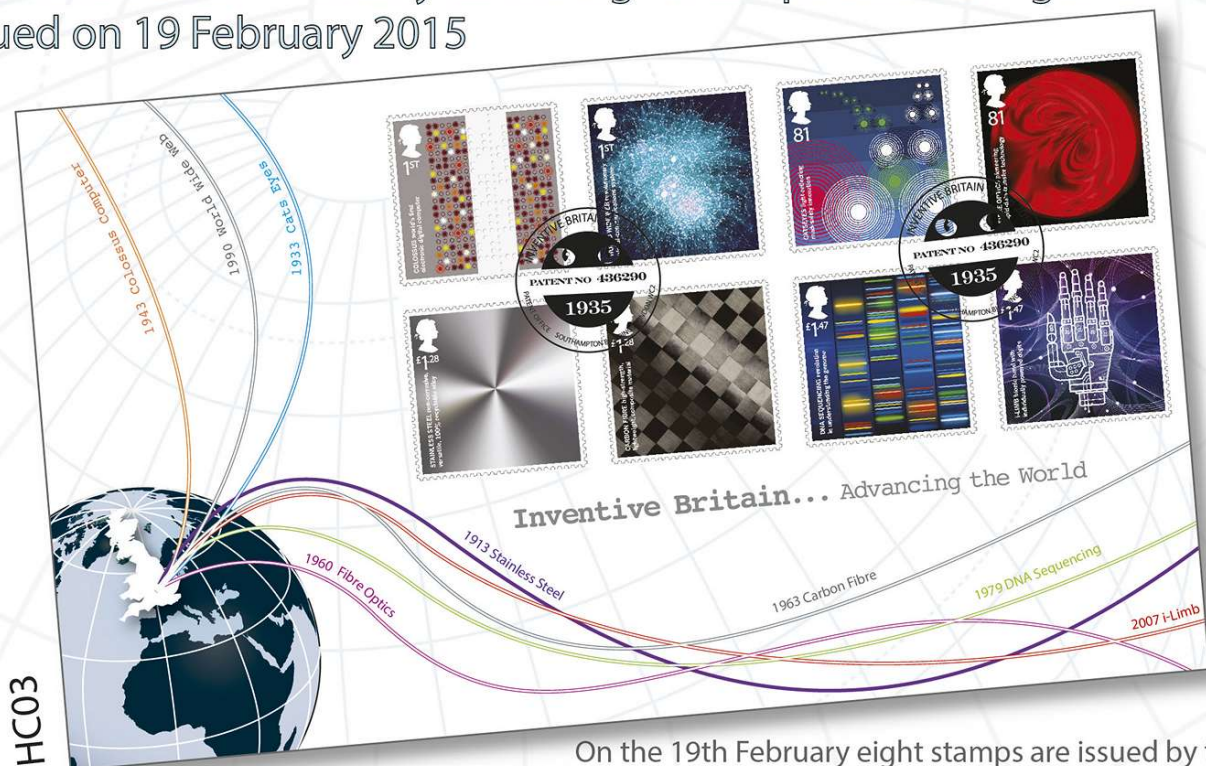


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# INVENTIVE BRITAIN

A limited edition First Day Cover. Eight stamps celebrating British inventions. Issued on 19 February 2015

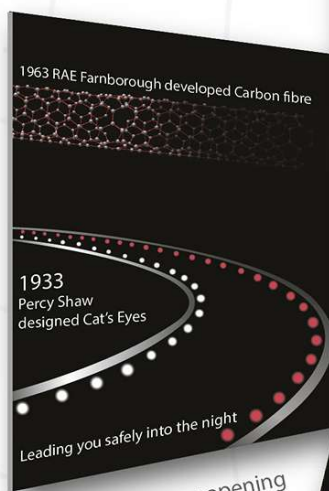
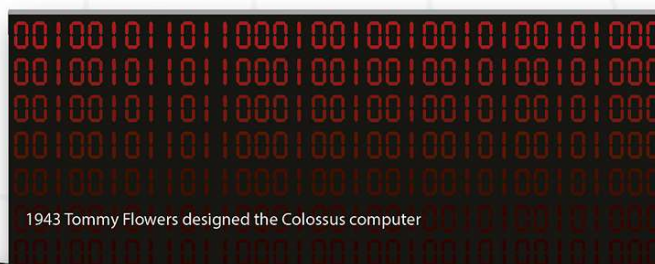


On the 19th February eight stamps are issued by the Royal Mail, celebrating different British inventions from 1913 to 2007. To commemorate this, Harriet's Collection have produced a First Day of issue cover, limited to 300 worldwide. Due to the limited number this could become a valuable collectors item.

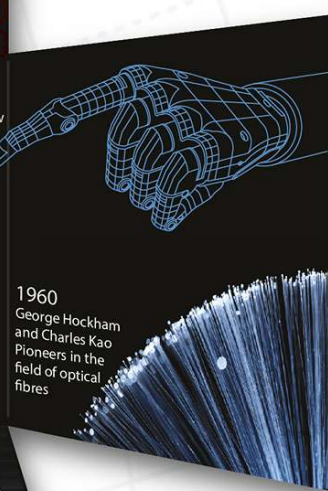
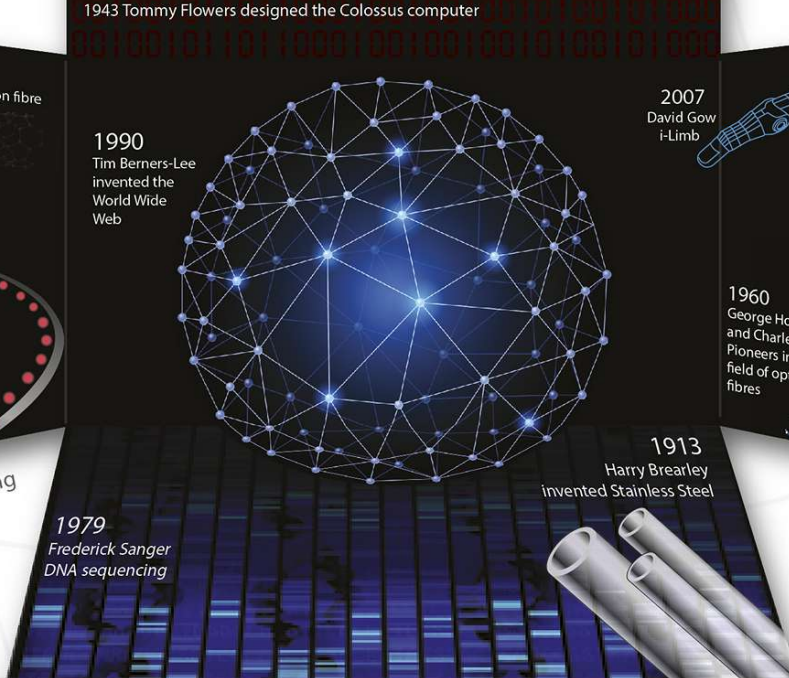


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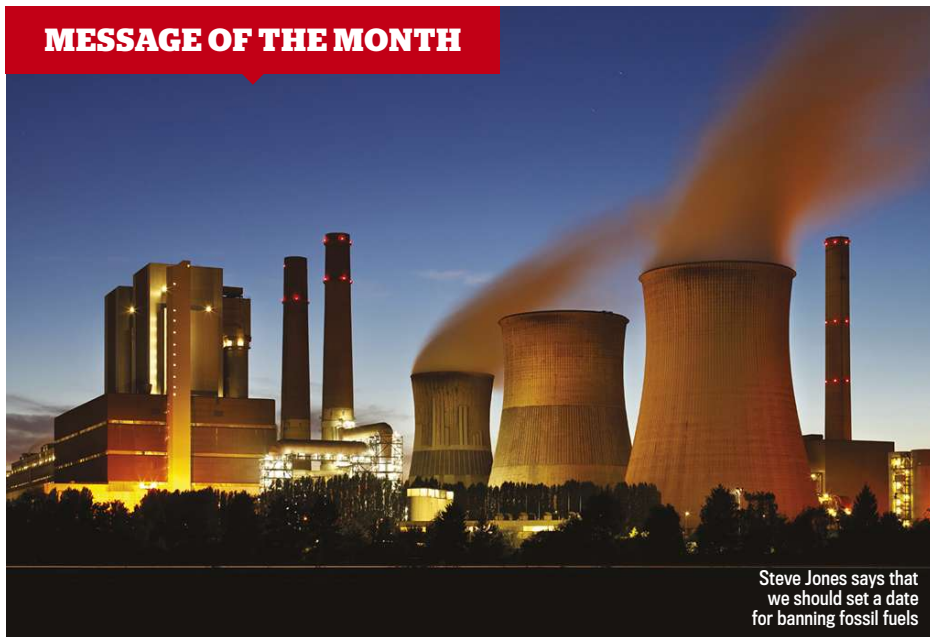
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## MESSAGE OF THE MONTH



Steve Jones says that  
we should set a date  
for banning fossil fuels

## Climate change not solved!

The article on climate change solutions in the January 2015 edition of *Focus* ('Climate change: problem solved', p56) suffered from two problems. First, virtually all the ideas suffered from the perennial issue that they are solutions that take a long time to become effective enough and big enough to make a difference. And this leads to the second complication. What is causing climate change is the build-up of greenhouse gases in the atmosphere (primarily carbon dioxide and methane) through the burning of fossil fuels. The elephant in the room is our technological civilisation's addiction to fossil fuels, and the real problem is how to tackle this dependence. This cannot be achieved via science and technology solutions alone.

What is required are major political and economic policy changes. The one effective means of achieving this is banning the burning of fossil fuels worldwide. This cannot be achieved instantly because the world economy would collapse. But it could be achieved by setting a future date by which time the internal combustion engine and all fossil fuel power plants would be banned. In the meantime, they could be gradually phased out and green replacements introduced, probably through fiscal means. The question then becomes whether we have enough time to implement this before it is too late and an irreversible tipping point in the global climate has passed.

**Steve Jones, Bedford**

## Alternative energy

I have reservations about the geoengineering projects advocated in the January issue's climate change feature. The Climate Geoengineering Governance (CGG) project finds that construction costs would be higher than envisaged. The Integrated Assessment of Geoengineering Proposals (IAGP) has found that trying to increase the reflectivity of the Earth, for example, could have significant unintended and unwelcome consequences.

Alongside continued development of clean energy and more funding for fusion research, we need to develop LFTRs (liquid fluoride thorium reactors). Thorium is a very abundant nuclear fuel. LFTRs would produce no greenhouse gases and much less radioactive waste than conventional nuclear power stations. They would be virtually failsafe – meltdown cannot happen because the fuel is already molten – and it would be almost impossible to divert any part of the fuel cycle for use in nuclear weapons.

**Mike Follows, Sutton Coldfield**

I was surprised not to have seen anything in your climate change article about harnessing the power of tidal currents. Surely such streams must be one of the greatest sources of energy there is?

**Bob Lillingston**



Water currents rotate the blades of tidal power plants

## + Write in and win!

The winner of next issue's Message of the Month wins a SteelSeries Stratus XL wireless gaming controller, worth £59.95. It connects via Bluetooth to your iPad, iPhone or iPod Touch. The controller has four pressure-sensitive action buttons and four shoulder buttons. [steelseries.com/stratusxl](http://steelseries.com/stratusxl)





Alan Thomas  
thinks that a  
Mars mission  
would be suicidal  
with current tech

## Suicide mission

The article 'One way to Mars' (February, p38) left me concerned that such a venture will be beyond our abilities for a long time. Putting a crew on Mars within the next few decades seems akin to early explorers using boats made from wooden frames tied together with rope. Through our 21st-Century eyes, setting out in such a flimsy craft would seem suicidal. The journey to Mars would be challenging, let alone living for years in the hostile environment with just a third of Earth's gravity and delayed communications with people back home. Far more achievable would be a station on the Moon. Evacuation in the event of an emergency would be possible on the Moon, but not on Mars.

**Alan Thomas, Shepperton**

## What's in the water?

With a sense of growing horror I read your recent article on adding lithium to drinking water as a mood stabiliser (February, p77). I find the idea extremely alarming. While it is supposedly for the benefit of our health, spiking a water supply would seem to be the perfect method of controlling a population. They could start adding chemicals to reduce scepticism preceding an election, or to increase conformity among the masses.

**Berwyn Powell**

The article on lithium in water made me feel angry. It mentioned that the US has been adding fluoride to water since the 1950s to avoid tooth decay. However, many countries all over Europe and the rest of the world banned water fluoridation. This is because most fluoridated areas suffered a huge health decline for decades. Lithium might lower depression and suicide rates, but surely people should have a choice over water in their homes without having to fit huge and expensive filters.

**Vinga Luksaite, East Sussex**

Vinga Luksaite says that people should be able to choose which substances go into their water supply

## GM crops: the drawbacks

I was appalled to read the article by Prof John Pickett (Subscriber bonus, February). It totally disregards the evidence throughout the world which suggests GM food is dangerous to our health, or creates risky situations that we have no idea how to deal with. The ideology of GM crops feeding the world fools nobody and only enriches the corporations that manufacture them. Their effect in third world countries has been devastating and is one of the reasons why many countries ban them.

**Penny Fidler**

I was disappointed that the article on GM plants did not give the pros and cons of this technology. Personally, I can see a great need for research in the particular problem of increasing food supplies for our growing population. I am also reminded that critics of GM point to many potential drawbacks, such as super weeds from natural gene transfer, farmers being tied to multinational seed suppliers with higher seed costs, and protein transfer from one species leading to someone having an allergic reaction to the new protein.

**Paul Hughes**

*Our Frontiers series is always written by a single scientist who is eminent in their field. But we will publish a follow-up looking at all aspects of GM crops. – Ed*



GM crops remain a controversial issue for many people

## Oops!

- We wrongly credited Megapixel on p9 of the February issue. It should have read Girts Kravalis.
- In December's lead Discoveries story (p19), 27,000 light-years is not equivalent to 10 trillion km. 10 trillion km is approx 1 light-year.

# FOCUS

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# DISCOVERIES

News and views from the world of science

EDITED BY  
**JASON GOODYER**



p22

## WERE DRAGONS EVER REAL?

A new species of dinosaur uncovered in China resembles the mythical beasts



p24

## EARTHS EVERYWHERE

Billions of planets in our own Galaxy could potentially support life



p28

## FEELIN' GREEN

Sea slug's feat could help us cure genetic disorders

### THE BIG STORY

## FIRST STEP TO ETERNAL YOUTH

Reversing the ageing process in human cells could one day treat genetic diseases

**T**ELOMERES ARE THE protective caps located on the ends of each strand of DNA. Now, Stanford University scientists have devised a means of increasing their length, which could have major implications for treating age-related diseases.

Telomeres prevent chromosomes from deterioration. In young humans they're typically made up of 8,000 to 10,000 nucleotides, the subunits of DNA. →

Telomeres are present at the end of DNA strands. Here, they can be seen as highlights on the end of the chromosome

PHOTO: SCIENCE PHOTO LIBRARY





Dr Helen Blau's research could help treat or prevent age-related diseases

➔ Telomeres shorten each time a cell divides, and when they reach a critical length the cell stops dividing or dies. This process is thought to play a key role in ageing.

In the study, the researchers treated human cells with modified messenger RNA. These are molecules that carry instructions from genes in the DNA to the cell's protein-making factories. The treated cells behaved like much younger cells, multiplying readily rather than stagnating or dying. Skin cells with telomeres lengthened by the procedure were able to divide 40 more times than untreated cells.

"We have found a way to lengthen human telomeres by as much as 1,000 nucleotides, turning back the internal clock in these cells by the equivalent of many years of human life," explains researcher Dr Helen Blau. "This new approach paves the way toward

preventing or treating diseases of ageing. There are also highly debilitating genetic diseases associated with telomere shortening that could benefit from a potential treatment."

The lengthening effect dissipates after around 48 hours, leaving the telomeres to continue to shorten with each cell division. This means that the treated cells don't go on to divide indefinitely – this would make the technique too dangerous to use in humans as there would be a risk of cancers developing.

"Existing transient methods of extending telomeres act slowly, whereas our method acts over just a few days to reverse telomere shortening that occurs over more than a decade of normal ageing," says researcher Dr John Ramunas. "This suggests that a treatment using our method could be brief and infrequent."

## TIMELINE

A history of ageing research

1825

British mathematician Benjamin Gompertz finds that mortality increases exponentially with ageing. This model is called the Gompertz Law of Mortality.

1961

American anatomist Leonard Hayflick (right) proposes the Hayflick limit. This is the maximum number of times that a cell is able to divide before cell division stops.



1977

Australian-American researcher Elizabeth Blackburn uncovers the molecular nature of telomeres while working as a postdoctoral fellow at Yale University.

1998

Andrea Bodnar discovers that the lifespan of cultured human cells can be extended with the addition of the enzyme telomerase.

## GOOD MONTH/ BAD MONTH

### It's been good for: OLDIES

IT SEEMS THAT you can teach an old dog new tricks – they just learn in a different way. A study at University College London has found that rather than becoming gradually better at integrating different kinds of information, like 19- to 35-year-old whippersnappers, the over-60s learn new skills by suppressing what's less important.



### ART LOVERS

APPRECIATING ART and music may help boost immunity. A UC Berkeley team has found that the positive emotions engendered by experiencing art may decrease levels of pro-inflammatory cytokines. These proteins are associated with bad health.

### It's been bad for:



### CREDIT CARD SHOPPERS

JUST FOUR transactions was all it took to identify 90 per cent of the users in a credit card database of 1.1 million people, using time and place information. That was the finding of scientists in Denmark, who say that more advanced technologies are needed to protect data privacy.

### FACEBOOK USERS

BROWSING ON FACEBOOK can lead to symptoms of depression if the site triggers feelings of envy among its users. Researchers from Missouri University carried out the study by questioning 700 Facebook users. The effect comes from users unfavourably comparing their own lives to those of others. Expensive holidays, new houses and happy relationships are the main contributors.





# NIGHTHAWK

AROUND-THE-EAR SEMI-OPEN HEADPHONES



audioquest®



## 1 MINUTE EXPERT

### Methylation



#### What's that?

It's a biochemical process in which methyl groups, 'packets' of atoms consisting of one carbon atom bonded to three hydrogen atoms, tag onto DNA. It can switch genes on and off and plays an important role in many different biological processes.



#### Right. So what's new?

Four independent studies tracked the lives of nearly 5,000 people for up to 14 years. Those with larger numbers of methyl tags on their DNA were found to have shorter life spans than the others. The methylation is an indicator of a person's 'biological age'.



#### Biological age?

Yes. Biological age is a measure of how aged a person's body is. It seems to be a more accurate marker of how long a person has left than going by the number of years they have lived.



#### Got it. So what does this mean?

The researchers say that those with a faster-running biological clock died younger. Smoking, education, cardiac diseases and diabetes did not influence how fast that clock runs. A previous study found that cancer did have an effect. It is hoped that these findings will result in a deeper understanding of ageing.



Artist's impression of Qijianglong being pursued by two carnivorous dinos

## PALAEONTOLOGY

# Here be dragons

THERE CAN BE few mythical beasts as synonymous with their country of origin as the dragon is with China. Now, palaeontologists have discovered a new species of dinosaur that resembles the legendary creature.

*Qijianglong*, meaning 'the dragon of Qijiang', was found at a fossil site first discovered by construction workers in 2006. It's about 15 metres long and lived 160 million years ago in the Late Jurassic. It belongs to a group of dinosaurs called the mamenchisaurids. These are unique to Asia and are known for their enormous necks, which can measure up to half their total length.

"*Qijianglong* is a cool animal. If you imagine a big animal that is half neck, you can see that evolution can do quite extraordinary things," says the University of Alberta's Tetsuto

Miyashita. "It is rare to find a head and neck of a long-necked dinosaur together because the head is so small and is easily detached after the animal dies."

Upon inspection, *Qijianglong* was found to have neck vertebrae that were filled with air, which is a unique trait among mamenchisaurids. This made the neck light, despite its huge size. Interlocking joints between the vertebrae suggest that the neck was more flexible when bending vertically than sideways.

The skeleton has been housed in a museum in Qijiang. "China is home to the ancient myths of dragons," says Miyashita. "I wonder if the ancient Chinese stumbled upon a skeleton of a long-necked dinosaur like *Qijianglong* and pictured that mythical creature."

## WHO'S IN THE NEWS?

### Barack Obama

President of the USA



#### What has he done?

At this year's State of the Union address, Barack Obama launched the Precision Medicine Initiative. This is a \$215m (£140m) research scheme with the goal of developing medical treatments that are tailored specifically to the genetics of patients, rather than taking a 'one size fits all' approach. It

is part of a broader effort to fund research and science.

#### What is 'precision medicine'?

According to the National Institutes of Health (NIH): "Precision medicine is an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment and lifestyle for each person."

#### That sounds pretty interesting. Tell me more...

The money is being divvied out among several organisations. At the centre of the project is a programme to give researchers across the world access to the health information of one million volunteers. This will help them to develop new medicines and treatment techniques.



## DAVID SHUKMAN

The science that matters



Lonesome George, the last tortoise of his kind, at the Galapagos National Park

# Too little, too late?

**B**ACK IN 2009, 200 years after the birth of Charles Darwin, I was on an assignment in the remote Galapagos Islands. This is the biodiversity hotspot that the great scientist made so famous. Our focus was on evolution and, to our relief, it was remarkably easy to film the animals. The blue-footed boobies and marine iguanas seemed to pose for the camera rather than flee from it.

But one afternoon came an unsettling experience. My cameraman and I were allowed into the holy of holies: the well-guarded enclosure that

was home to the most famous giant tortoise in the world, Lonesome George. He was the last of his kind, a subspecies on the brink of extinction.

Darwin had written about extinction as a part of the rise and fall of competing forms of life, the flipside of evolution. Now, the towering dome of Lonesome George's shell shifted in the speckled light under a tree and his ancient head turned towards us. I know I was projecting my own emotions but, at the time, it felt that his eyes conveyed a desperate sadness. He died a few years later.

Some brilliant conservation schemes have restored the giant panda and the black-footed ferret. But their numbers never quite fell into single digits; assisted reproduction had a chance of working without causing inbreeding. Once the last band of survivors becomes too small, there is little hope.

That is the case with one of Africa's greatest mammals, the northern white rhino. Hunted for their horns, there are now just five left on the planet. One idea is to try IVF with eggs and sperm harvested before the animals die out. Another plan

is to gather stem cells and to freeze them in the hope that some day in the future it will be possible to create embryos.

And this raises a dilemma. Some argue that because we caused the demise of the species, we have a duty to use modern science to restore it. Others say that the medical interventions – probes and sampling and sedations – are harmful in themselves. And, all the time, yet more species face oblivion.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

## THEY DID WHAT?!

### Chemists unboil an egg

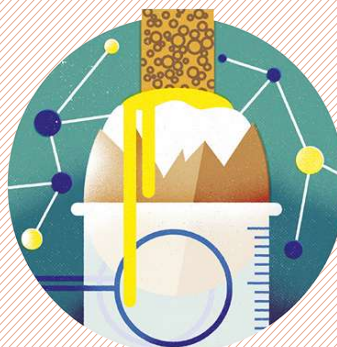
#### What did they do?

A team from the University of California, Irvine figured out a way of untangling the proteins in cooked egg whites and allowing them to refold. The

resulting effect was as if the egg had been 'unboiled'.

#### How did they do it?

First, they cooked the eggs for 20 minutes so they were hard boiled. They then liquefied the cooked egg white with urea. This is a nitrogen-rich substance that is found in the urine of mammals. They then used a 'vortex fluid device'



that applied forces to the tiny strands of protein in the white. This separated the proteins back to their clear form.

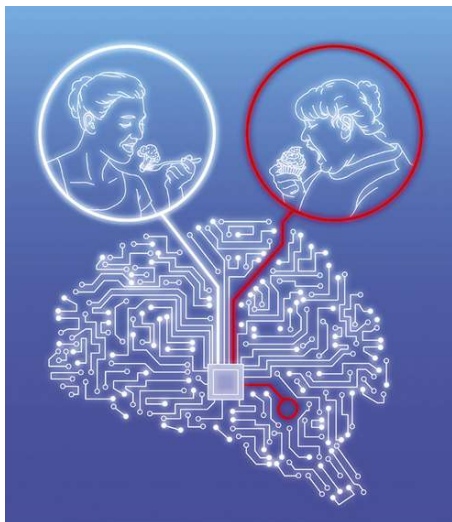
#### What's the point?

Being able to reform proteins from yeast or *E. coli* bacteria may lead to more efficient methods of making proteins, which could help create cheaper cancer treatments.



## HEALTH

# Overeating solved?



IF YOUR SWEET tooth is causing you to pile on the pounds, you may want to read on. Researchers at MIT have identified a neural circuit that controls compulsive sugar consumption.

Compulsive overeating is a reward-seeking behaviour that's similar to drug addiction. But because eating is needed for survival, any successful therapies need to separate the neural mechanisms that cause overeating from those responsible for normal eating.

The team found success when manipulating a neural pathway connecting the lateral hypothalamus, an area of the brain involved in hunger, to the ventral tegmental area, which is involved with the brain's natural reward circuitry.

Activating this pathway caused well-fed mice to spend more time eating. It also increased their consumption of a sugar solution placed separately from their food, even when they had to cross an electrified platform to reach it. Inhibiting this pathway in hungry mice reduced the sugar-seeking behaviour without decreasing normal food consumption.

"Although obesity and Type 2 diabetes are major problems in our society, many treatments do not tackle the primary cause: unhealthy eating habits," says author Dr Kay Tye. "Our findings are exciting because they raise the possibility that we could develop a treatment that selectively curbs compulsive overeating without altering healthy eating behaviour."

## SPACE

# Why there's an Earth-like planet around every star

PLANETARY SCIENTISTS HAVE calculated that there are billions of Earth-like planets in our galaxy that could potentially support life.

A team at the Australian National University made the calculation using the Titius-Bode law, along with knowledge of the thousands of exoplanets that have been discovered by the Kepler Space Telescope.

The Titius-Bode law was created 200 years ago and can be used to predict the positions of planets orbiting a star. Due to the method used to spot them, the Kepler Space Telescope is more likely to find

planets that are very close to their stars. Using the Kepler data as a starting point, they then applied the Titius-Bode law to predict the existence of planets further away from their stars.

They found that the standard star has roughly two planets in the so-called Goldilocks zone. This is the distance from the star where liquid water, crucial for life, can exist. If the calculation is correct, it would mean there are 200 billion Earth-like planets in the Milky Way alone.

But don't get too excited just yet. The university research team says it is highly





Kepler-62f is an Earth-like planet that orbits in the habitable region of its star

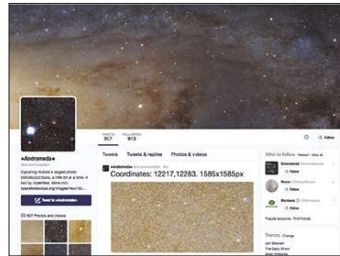
unlikely that these exoplanets are home to thriving alien civilisations.

"The ingredients for life are plentiful, and we now know that habitable environments are plentiful," says researcher Dr Charley Lineweaver. "However, the Universe is not teeming with aliens with human-like intelligence that can build radio telescopes and spaceships. Otherwise we would have seen or heard from them. It could be that there is some other bottleneck for the emergence of life that we haven't worked out yet. Or intelligent civilisations evolve, but then self-destruct."



## CLICK HERE

New websites, blogs and podcasts

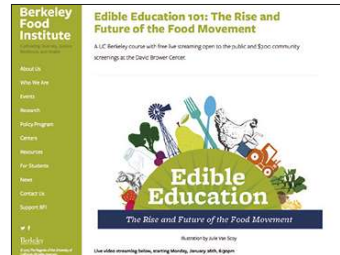


### ANDROMEDA BOT

[twitter.com/AndromedaBot](https://twitter.com/AndromedaBot)

Hubble released the largest ever photo of the Andromeda galaxy in January 2015. This Twitter account tweets a new section of the picture every hour, allowing you to see individual stars in

all their glory. According to the European Space Agency, you'd need over 600 HD TV screens to display the image in full.



### EDIBLE EDUCATION

[food.berkeley.edu/edible-education-101/](http://food.berkeley.edu/edible-education-101/)

Ever felt like you should know more about where your food comes from, and how it could be more sustainable? This lecture course at the University of California, Berkeley, is

exploring those questions and more. The first lecture was on 26 January, but course materials are freely available online.



### JURASSIC WORLD

[jurassicworld.com/dinosaurs/](http://jurassicworld.com/dinosaurs/)

*Jurassic World* is almost here, and if you want to brush up on your dinosaur knowledge, then look no further than the film's website. The jury is still out on exactly how

scientifically accurate the film will be (the dinos in the trailer lacked feathers) but, either way, everyone's going to be talking about them come summer.



### BRAINWAVE

<http://bit.ly/1ESDRcT>

The Open University's *Brainwave* app consists of five games that test your cognitive ability. But this isn't your average brain-training game. It can tell you if you're a morning or evening person based on your scores at different times of day. Your results will then be made anonymous and uploaded to help with real psychological research.



KELLY OAKES is science editor at BuzzFeed. She tweets from @kahoakes



# 10 DISCOVERIES THAT WILL SHAPE THE FUTURE



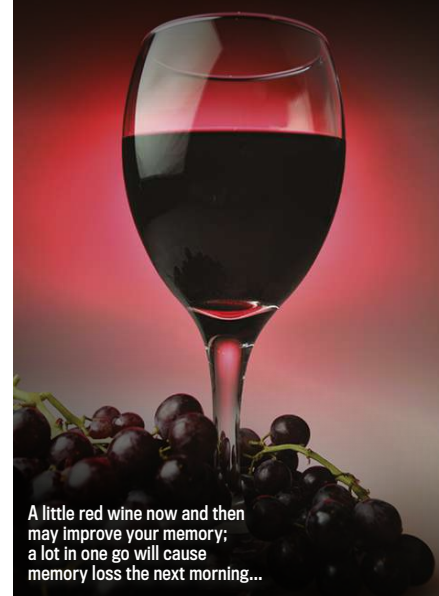
## 10 Temporary tattoo to measure blood glucose

IT SEEMS TATTOOS may no longer be the preserve of footballers, rappers and Shoreditch hipsters. A group at the University of California has created a temporary paper-based tattoo that measures blood glucose levels using a mild electric shock. **The technology could replace the current finger-prick method.**

Take a blood test without the need for a needle

## 9 Compound in wine may aid memory

RESVERATROL, AN ANTIOXIDANT found in the skin of red grapes, as well as in red wine, may help to **prevent age-related memory decline.** Researchers at Texas A&M University found that rats treated with the compound showed improved spatial learning and memory, and double the rate of growth of new neurones.

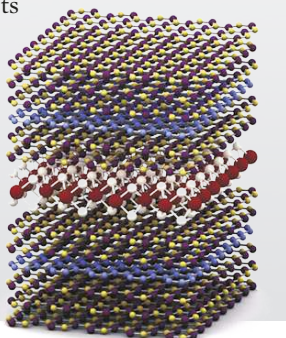


A little red wine now and then may improve your memory; a lot in one go will cause memory loss the next morning...

## 8 Graphene LEDs

GRAPHENE COULD ENABLE engineers to create the first generation of semi-transparent devices, according to research at the University of Manchester. The team constructed LEDs by combining different 2D crystals of graphene. **The tech could be used in everything from simple lighting to lasers and flexible displays.** The components

are just 10-40 atoms thick and emit light across their whole surface.



## 7 Stem cell treatment to reverse baldness

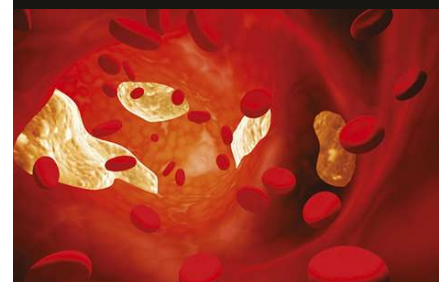


American researchers have turned stem cells into the cells that control hair growth

GOING A BIT thin on top? Fear not, **a team in the US has successfully used human pluripotent stem cells to generate new hair.** They coaxed the stem cells to become dermal papillae, which are cells that regulate hair follicle formation and growth. The treatment has been successful in rats, and the researchers now hope to try it in humans too.

## 6 Drug preserves brain function after stroke

RETIGABINE, A DRUG currently used for treating epilepsy, could **significantly reduce the debilitating effects of strokes.** A team in Texas found that the drug greatly reduced damage to brain tissue when tested in mice that had suffered strokes. It also helped to preserve motor functions such as balance and coordination.





## 5 Liquid sunshine

THE FUEL IN your car may one day be produced by genetically modified bacteria. Harvard scientists have designed a system that uses an 'electric leaf' to liberate hydrogen from water using sunlight. The bacterium *Ralstonia eutropha* then absorbs the hydrogen and **combines it with carbon dioxide to create the liquid fuel**, isopropanol.

## 3 Drought-tolerant plants

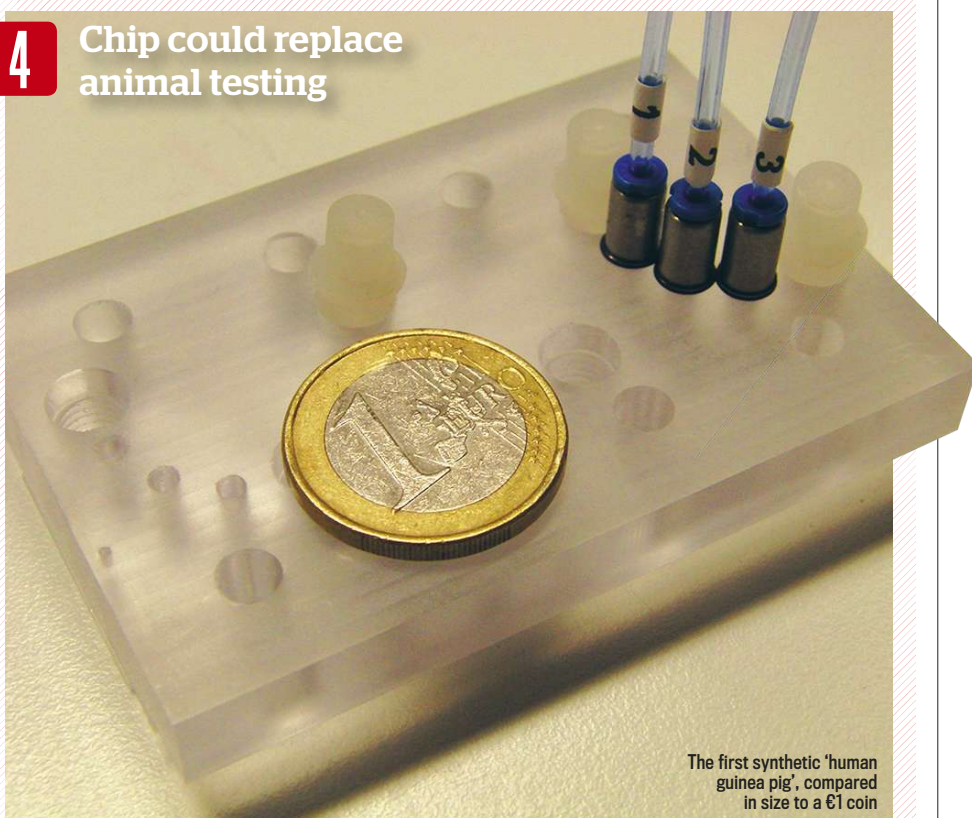
HUMANS ARE NOT the only ones struggling with the effects of climate change – plants are too. Help may be on the way, as researchers in California have used synthetic biology techniques to help plants conserve water by encouraging the production of a specific protein.

**The research could lead to hardier, more drought-resistant plants.**

Hardier plants could soon be arriving in our gardens



## 4 Chip could replace animal testing



The first synthetic 'human guinea pig', compared in size to a €1 coin

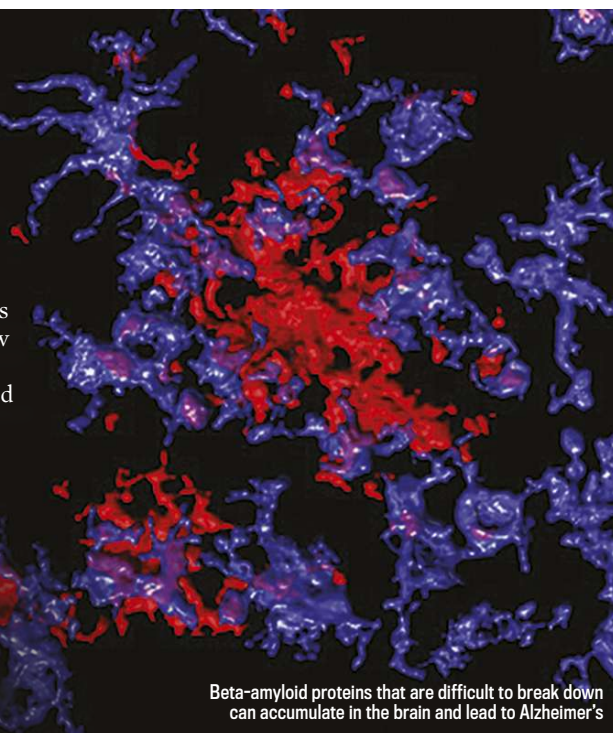
A TEAM IN BERLIN has produced a multi-organ chip that could **reduce the need for animal testing**. Cells from various organs can be placed in the chip

and used to simulate processes that occur within the human body. The substance to be tested is then introduced into the chip and its effects are monitored.

## 2 Immune cells may help fight Alzheimer's

ALZHEIMER'S DISEASE IS an irreversible, progressive brain disease that causes problems with memory, thinking and behaviour. Brains with Alzheimer's disease show build-up of a sticky plaque. This is made of a protein called beta-amyloid and induces memory loss. A team in California has found that inhibiting a substance called interleukin-10 in mice activates an immune response to clear the brain of plaques, restoring brain cells that were damaged.

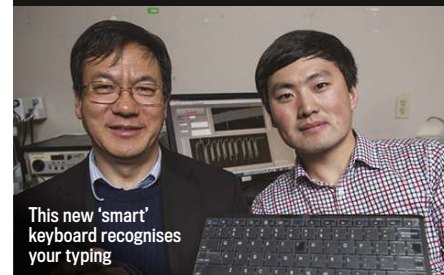
**The work could lead to more effective human therapies.**



Beta-amyloid proteins that are difficult to break down can accumulate in the brain and lead to Alzheimer's

## 1 Intelligent keyboard

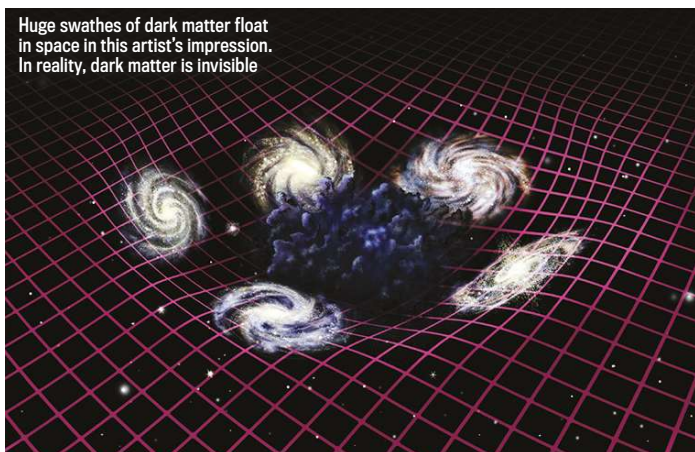
ALWAYS FORGETTING YOUR passwords? There may soon be a solution. Engineers at the Georgia Institute of Technology have created a keyboard that can identify users by their typing style. The keyboard is capable of recording key strokes to create a profile for users. **It could be used instead of, or as well as, regular passwords for security.**



This new 'smart' keyboard recognises your typing



Huge swathes of dark matter float in space in this artist's impression. In reality, dark matter is invisible



"Our candidate particle sounds crazy, but currently there seem to be no experiments or observations which could rule it out," says co-author Dr James Bateman. "Dark matter is one of the most important unsolved problems in modern physics, and we hope that our suggestion will inspire others to develop detailed particle theory and even experimental tests."

"At the moment, experiments on dark matter do not point in a clear direction. Given that the Large Hadron Collider at CERN has not yet found any signs of new physics, it may be time that we shift our paradigm towards alternative candidates for dark matter," explains co-author Dr Alexander Merle.

**NATURE**

## Solar-powered slug

"There is no way that genes from an alga should work inside an animal cell," says co-author Prof

Researchers hope to mimic this process to correct genetic diseases in humans.



# PATENTLY OBVIOUS with James Lloyd

## Inventions and discoveries that will change the world



## Silent movies

Patent number: US 8,934,879

## Doze on demand

WHEN CAMOMILE TEA doesn't do the trick, here's a new way to help you drop off: Sprayable Sleep. The concoction has been developed by a team in the US and contains just three ingredients: water, tyrosine (an amino acid) and melatonin – the hormone that regulates our circadian rhythms and is often used to treat sleeping disorders. Once in contact with the skin, Sprayable Sleep is absorbed by the body, providing a release of melatonin that the makers say gives a natural-feeling sleep without the grogginess often associated with sleeping pills.

**Patent pending**

## Pocket power

ARE YOUR GADGETS always running out of juice? A portable power generator could be the solution. Kraftwerk is a lightweight device that uses fuel cell tech to convert camping gas into electrical power. Developed by materials scientist Dr Sascha Kühn, the device is capable of charging 11 iPhones with just one load of gas. Using gas instead of batteries means that kraftwerk can be quickly refilled. As you don't need to be anywhere near a power socket, it's a perfect solution for those camping trips.

**Patent pending**



# The best cost-saving energy device ever?

**Experience an invigorating shower like no other –  
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Introducing the Jetstorm – the newest addition to our groundbreaking range of revolutionary water-efficient shower heads from Ecocamel. With several years of scientific research, we have been able to produce a shower head that instantly increases pressure and performance to create an exhilarating shower experience, whilst using significantly less water. So confident are we that you'll love your new powerful shower, we're offering all Focus magazine readers a 30-day money back guarantee\*. Plus for a limited time only, 40% off the RRP and a FREE hose worth £10.

## The science

This pioneering new shower head is called the Jetstorm because of its patented dual valve 'AirCore' technology. Developed to infuse a storm of minute air bubbles into each droplet which are then blasted, jet-like, onto your skin... we guarantee you'll increase your shower's power instantly and reduces your water consumption considerably! The droplets – now bursting with air – are so much lighter than normal and, rather than just bouncing off you, they saturate and spread all over your body – a sensational experience.

## Save more than just water

These are tough economic times – with a 'triple-dip' recession looming and energy prices set to rise by up to 19%, everyone is trying to cut their costs. The Jetstorm not only helps cut your water bills but reduces your energy bills too! Using less water means using less energy to heat it, saving you ££££s on your energy bills – **SIMPLE!**

## Do I have to call a plumber?

Absolutely not, it really could not be easier. It takes just a few seconds to unscrew your existing shower head and pop on your new water-efficient Jetstorm.

## Which Jetstorm is right for me?

If you have a normal gravity, main-pressure or pump system just order the Original Jetstorm. If you use a low-pressure system or electric shower, ask for the Jetstorm E.



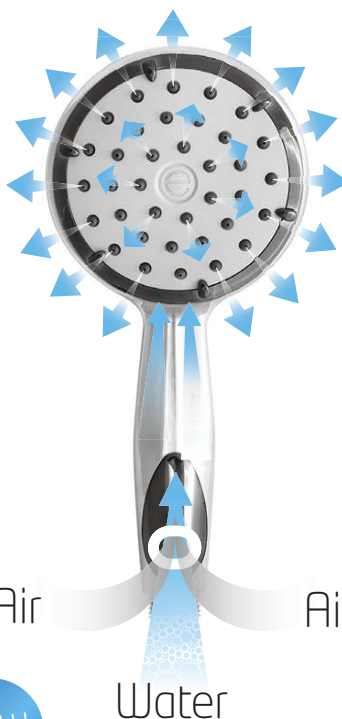
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Sarah Lonsdale – Sunday Telegraph

*"We tried out five eco shower heads checking their flow rate and quality of experience. Our favourite is the Ecocamel Jetstorm, it felt powerful and invigorating."*

Good Housekeeping Institute

*"Definitely one of the simplest ways to make financial savings in the home without having to make too many changes to your routine."*

Justin Harper – Daily Mail

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Mr. T. G. General Manager, The Days Inn Hotel, Hyde Park

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K. Sawbridge, Ops Director, Alfa Leisureplex Holiday Group



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For standard systems

☐ 1 Jetstorm-E + FREE HOSE £29.95 + £4.95 p&p = **£34.90**  
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## INSIDE SCIENCE

# ROBERT MATTHEWS

Why you should take studies of human behaviour with a pinch of salt

**D**ID YOU SEE the story about how personality is the result of upbringing rather than genes? How about the one claiming that happy couples often have similar hormones, or that city living messes with sleep patterns? I love these kinds of stories – right up until I get beyond the headline and read the lame line “at least in birds”. Or in aardvarks, tadpoles or some other creature.

The feeble logic behind such stories is that the outcome of studies of animals might be relevant to humans. Well, it might – though I generally doubt it very much. In any case, the only way to tell is by doing experiments on humans, and until then I’m really not interested. Yet even my jaundiced attitude presumes that studies of humans will lead to genuine insights. Sadly, that is far from guaranteed.

Every week the media reports new research showing that, say, people are most prone to arguments in late November. Chances are that the researchers actually discovered that US students row with their parents during Thanksgiving.

Okay, I made up that scientific nugget, but the dangers of believing claims based on human studies are real enough. A few years ago, a team led by psychologist Prof Joseph Henrich of the University of British Columbia found that much of what science supposedly knows about ‘human’ nature is based on studies of a very special set of people: those from what they termed WEIRD societies (western, educated, industrialised, rich and democratic).

It’s not just where the participants hail from that’s a problem – what they’re asked to do is pretty questionable as well. In his best-selling book *Thinking, Fast and Slow*, Nobel-winning psychologist Daniel Kahneman recalls his surprise at learning that experiments on human risk-taking often involve piffling sums of money. It’s therefore unlikely that such studies will tell us much about how we make life-changing decisions.

But perhaps the biggest problem with so much human-based research is how it ignores the subtleties of behaviour. Take the case of arguably the most famous of all psychology experiments, performed by the brilliant US psychologist Stanley Milgram in the early 1960s. Milgram wanted to investigate how ordinary people from a civilised society could commit acts of appalling barbarity, as Germans did under the Nazis, for instance.

Stanley Milgram’s study suggested that even nice people can be persuaded to do nasty things



**“Milgram wanted to investigate how ordinary people from a civilised society could commit acts of appalling barbarity”**

He recruited people to take part in a study of memory, which involved giving an unknown person increasingly powerful shocks as punishment for mistakes. In reality, the victim was just an actor pretending to be in pain, and the study was trying to find out how to persuade people to continue to give shocks, despite the apparent agony they were inflicting. Astonishingly, almost two-thirds of the participants obeyed instructions to continue giving shocks, all the way up to apparently lethal levels.

Milgram argued that this showed nice people will commit nasty acts if they’re able to convince themselves they’ve shifted the responsibility. Yet new research suggests Milgram missed key insights by categorising people as obedient or not. Analysis of voice recordings during the experiment has revealed that the way people are instructed to continue is crucial. It turns out that simply telling people they have no choice but to continue often triggers rebellion. That’s a new and comforting

insight from Milgram’s otherwise depressing study. It’s also one worth pondering whenever scientists insist we have no choice but to accept their findings. ■

**ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham**



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# EVERYDAY SCIENCE

# HELEN CZERSKI

Starter snowboarders learn to love friction...

**A**FTER SLITHERING INELEGANTLY to a stop, I sat down slightly too hard on the snow and surveyed the scene. The board attached to my feet was decked out in a colour scheme oozing daredevil chic (implying, unreasonably, that I also belonged in that category). A bit further down the slope was my snowboarding instructor, almost entirely hidden behind beard and goggles, and clearly accustomed to waiting patiently. Beyond him was a lot of white, flowing down the mountain towards distant hot chocolate, warmth and safety. "You'll like this," the beard said, "I'll draw you a diagram."

He traced out a curve for the path of the snowboard, and another curve for the path of my centre of mass. I suddenly felt a wave of comeuppance arrive. I've been drawing diagrams like that for years: idealised situations where point-like objects respond to uncomplicated forces are the bread-and-butter of physics. But these diagrams almost always leave something important out. And the problem with my current situation was that this time, the important thing wasn't ever really there. There was almost no friction. My first snowboarding lesson was actually a lesson in navigating the idealised world I'd been drawing for years. And it was painful.

Friction gets a bad rap, but what it really gives us is control. It heads off the conservation laws – conservation of momentum and conservation of energy – by providing an escape valve. Walking is only possible because of friction with the floor. Wheels wouldn't work if they couldn't grip. Energy leaches away via friction, so we have to consciously supply more energy to keep going.

There are alternative ways to control our movement, but snowboarding really highlights their limitations. You can change the position of your centre of mass to rotate about a

pivot point. You can plough up snow in front of your board to give you something to push against. But there's no room for misjudgment – get it wrong and your coccyx is going to suffer. This is Newton's laws of motion writ large: a body will continue either at rest or in motion unless a force is applied to it. Forces accelerate you, and for every action there's an equal and opposite reaction. That last one made me terrified of the trees.

Of course, you do need a bit of friction for snowboarding to work. But the thrill of the sport comes from the freedom of mostly doing without



**“Friction, far from being the curse of our world, is one of the most useful tools we have. And I have the bruises to prove it”**

friction, while maintaining control of the tiny bit that's left so that you don't kill yourself. As I looked down the hill, a baggy blur of colour swooshed past, clearly as close to an idealised frictionless diagram as a human could get. "Turning is useful because it slows you down," my instructor said, before zooming off to demonstrate his point. As I stood up to re-start my semi-controlled falling, it became obvious that energy loss – that universal nuisance of the physical world – had suddenly become the most precious tool I had. I wondered whether Newton had been ice-skating before he wrote down his laws of motion. He did live in an era when there were frost fairs on the River Thames, but I've never heard anyone mention a link.

I loved that day on the mountain, and maybe I've caught the snowboarding bug. But exciting as the idealised world of frictionless

physics was, I wouldn't like to live there. Friction, far from being the curse of our world, is one of the most useful tools we have. And now I have the bruises to prove it! ■

**DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses***



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# INTO THE FUTURE STEPHEN BAXTER

Jules Verne's 19th Century science fiction continues to inspire today

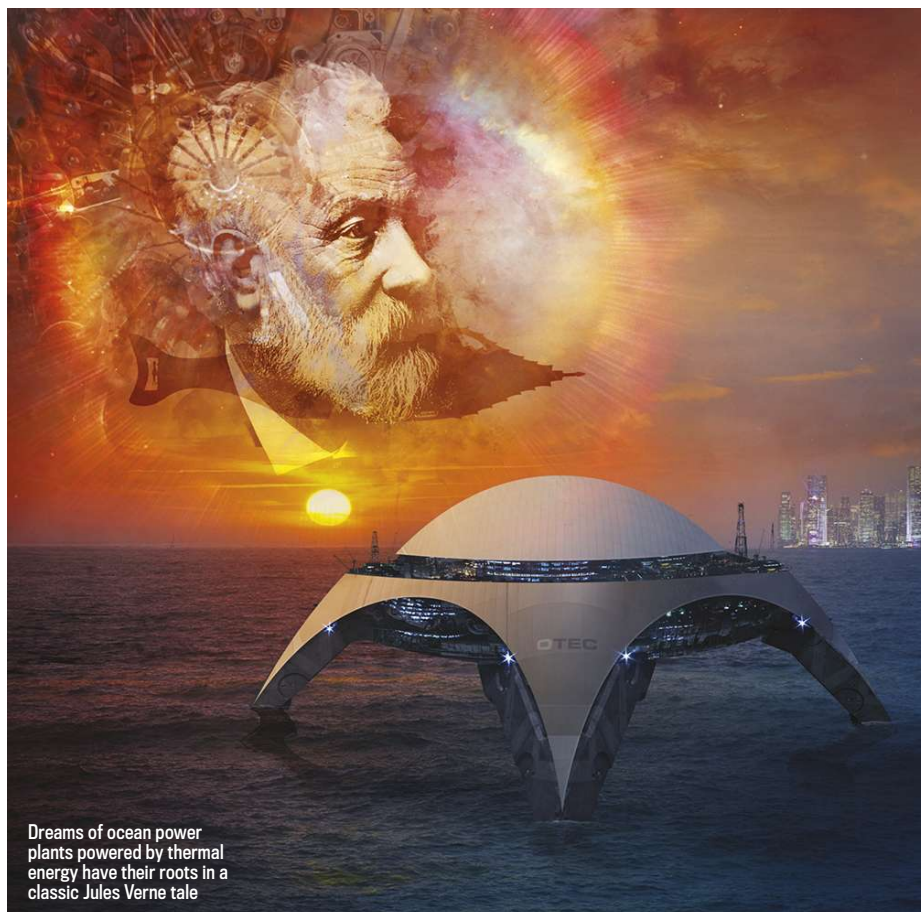
**J**ULES VERNE'S NOVEL *20,000 Leagues Under The Sea* (1870) tells the story of Captain Nemo and his submarine, the Nautilus. And today, 110 years after Verne's death in March 1905, we are on the verge of extracting energy from the ocean, just like Nemo does in the tale.

Jules Gabriel Verne was born in 1828 in a French seaport. He was always fascinated by tales of discovery and adventure, but by the time he wrote *20,000 Leagues*, his world had been transformed by technologies like trains, high-speed steam frigates and transatlantic telegraph cables. Verne didn't invent the submarine, but studied an early French Navy vessel called the Plongeur as the model for Nemo's craft.

Thanks to his care over technical accuracy, Verne achieved an uncannily prophetic hit-rate. *From The Earth To The Moon* (1865) inspired the 20th Century NASA engineers who found a way to reach the lunar surface – except they used rocket-driven spacecraft rather than Verne's cannon. And as reported in last December's *Focus*, the novel *Journey To The Centre Of The Earth* (1864) is capturing the imaginations of modern scientists who seek to probe the Earth's mantle. Today, engineers are devising systems not unlike Verne's for powering ocean-going craft.

But where does Nemo get the electrical power for his submarine? From the heat of the sea itself: specifically, the temperature difference between the warm upper layers and the colder depths. Nemo says: "By establishing a circuit between two wires plunged to different depths, [one could] obtain electricity by the difference of temperatures to which they would have been exposed." That is, heat energy from the ocean is converted to electrical energy.

This obvious-sounding idea was first developed in a practical design by French physicist Jacques-Arsène d'Arsonval just 11 years after *20,000 Leagues* was published. In the 20th Century, as renewable sources of energy were explored, the idea was revived under the moniker 'ocean thermal energy conversion' (OTEC). Modern systems don't use Nemo's wires. Instead, they have pipes containing a liquid with a low boiling point, such as ammonia, which boils in the warm surface layers. This



**“Where does Captain Nemo get the electrical power for his submarine? From the heat of the sea itself”**

drives a turbine, before being re-liquefied by cold water pumped up from the depths. In principle, OTEC could provide the world's current energy demand thousands of times over.

Ambitious OTEC schemes captured imaginations during the 1970s oil crisis, but there were practical problems associated with pumping tonnes of cold water every second. Since then, new techniques such as the use of ultra-light, ultra-strong materials for the cold water extraction pipes have transformed the possibilities for the technology. In 2013, aerospace giant Lockheed Martin announced plans to construct a 10-megawatt plant off the coast of China. Other pilot schemes are in development. Environmentalists flag the dangers of algal blooms and other disruptions, but engineers are confident that such problems can be minimised.

In Verne's book, Nemo was told that his Nautilus was a century ahead of its time. And so it was: the US Navy's first operational nuclear submarine (SSN-571), launched in 1954, was called Nautilus. And in years to come, Verne's steampunk visions will continue to inspire. ■

**STEPHEN BAXTER is a science fiction author who has written over 40 books. His latest is *Ultima*, published by Orion**

ILLUSTRATOR: ANDY POTTS



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Discover the

# UNIVERSE NEXT DOOR

...where time runs backwards

A brand new idea about the Big Bang reveals why our clocks always go forwards, explains **Marcus Chown**

**T**HE BIG BANG may not have spawned one universe, it may have spawned two. One is our Universe, where time runs normally. The second is a twin universe in which time runs backwards. The latter universe, located 'on the other side of the Big Bang', would appear completely normal to its inhabitants, with stars and galaxies congealing from the cooling debris of the Big Bang much like in our Universe. If it were







possible for us to look back through the Big Bang to this cosmic doppelgänger, its backward-running time might make it appear like a universe in reverse, contracting to a Big Crunch.

Dr Julian Barbour of the University of Oxford, Dr Tim Koslowski of the University of New Brunswick and Dr Flavio Mercati of the Perimeter Institute in Ontario made this extraordinary discovery while trying to understand one of the great puzzles of physics: why there is a direction of time. We commonly associate this 'arrow' of time with the way in which eggs break, people grow old and castles crumble. We never see eggs unbreak, people grow young and castles un-crumble. But *why* we do not isn't as obvious as it might seem.

## ARROW OF TIME

The problem is that all the fundamental laws of physics are 'time symmetric' – they permit processes to work equally well backwards as forwards. For instance, an atom can spit out a photon of light and it can also suck in a photon of light. If you were shown a film of an atom doing something, you would never be able to tell whether the movie was being run forwards or backwards. Both events would appear perfectly reasonable. In contrast, if you were shown a picture of a complete teacup and the same cup smashed into tiny shards, you would be in no doubt that the picture of the broken cup was taken later.

This so-called thermodynamic arrow of time is associated with the change from order to disorder. And, obviously, this can happen only if the Universe was in a more ordered state in the past. The trouble is that an ordered state is a special state – it smacks of something set up by God, which makes it uncomfortable for physicists to accept.

The 19th Century German physicist Ludwig Boltzmann speculated that, although the Universe on the whole was disordered, by some incredible fluke we happen to live in a super-ordered location. It could be considered a rare 'statistical fluctuation' – the cosmic equivalent of an unbreaking cup. Most physicists consider this an unsatisfactory conclusion since it merely explains the specialness of our Universe in terms of some other specialness.

Long after Boltzmann's time, it was discovered that the Universe burst into being 13.82 billion years ago in a titanic explosion called the Big Bang, and that all the galaxies, including our Milky Way, congealed out of the cooling debris. This put the question of the origin of the arrow of time into sharper focus. Now it appeared that the Big Bang



**“We never see eggs unbreak, people grow young and castles un-crumble. But *why* we do not isn't as obvious as it might seem”**



Above: You never see castles un-crumble, which puzzles physicists

Right: The Universe's matter rapidly expanded after the Big Bang took place

must have been in a highly ordered and special state. Again, this is something that physicists find equally difficult to stomach.

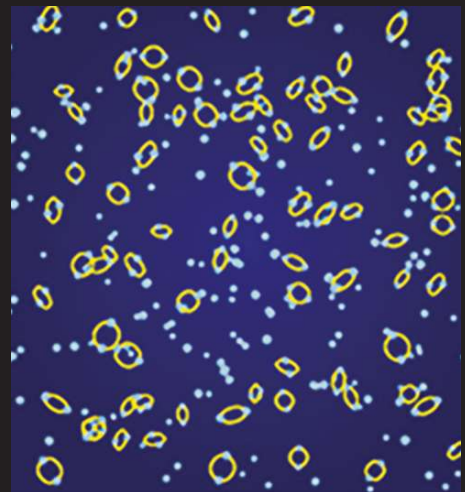
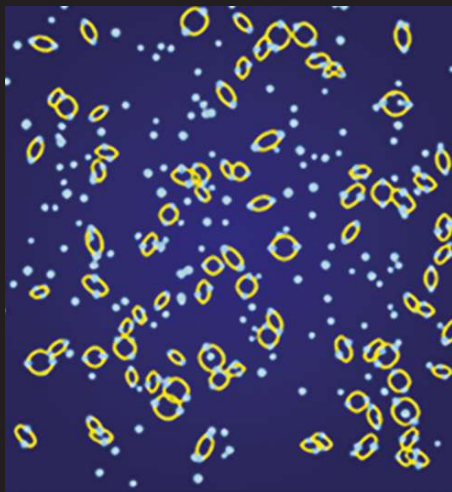
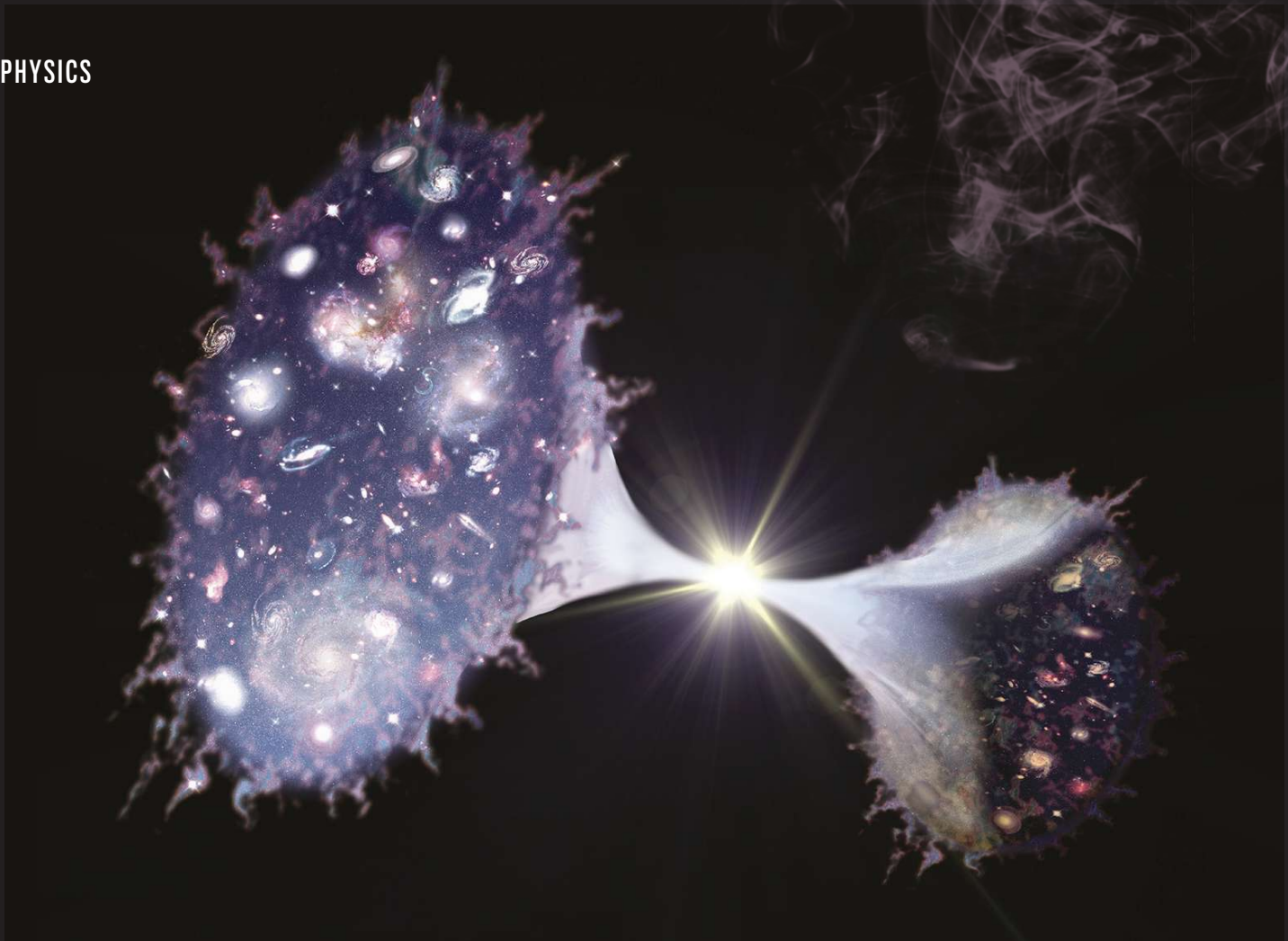
Another logical possibility is that the Universe goes from order to disorder. This is not because it was super-ordered in the past, but because there is an infinite scope for increasing disorder in the future. This possibility has been pointed out by physicists Sean Carroll and Jennifer Chen of the California Institute of Technology in











**Top:** The Big Bang may have spawned two different universes

**Above:** A simulation of 1,000 particles floating in space. The central image shows the start point. The other images show the two possible future scenarios

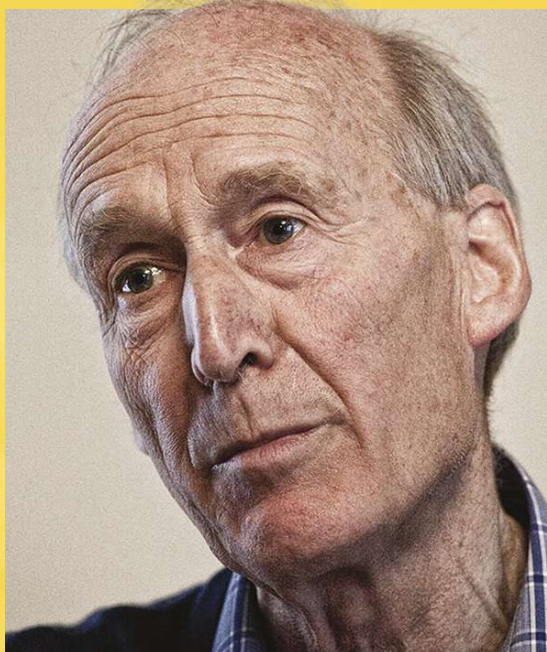
➔ Pasadena. One popular theory of the origin of the Universe is called eternal inflation. Here, the Universe keeps spawning baby universes, which in turn spawn their own baby universes, and so on. Carroll and Chen contend that this ensures the Universe becomes ever more complex and disordered, so there will always be scope for increasing disorder.

What the super-ordered past and the super-disordered future have in common is they are, respectively, 'initial' and 'final' conditions imposed on the laws of physics. But what if the laws of physics themselves actually impose an arrow of time? In research published in October 2014, Barbour and his colleagues made an

unexpected discovery suggesting that this could indeed be the case.

Barbour's team simulated 1,000 massive particles floating in space. In previous work, other physicists have discovered that such a group of particles, influenced only by the mutual attractive force of gravity, will tend to cluster in small groups after a long period of time. These are generally seen as pairs of masses, orbiting each other. Barbour and his colleagues used this as their starting point and were able to simulate what would happen to their 1,000 particles, but crucially without any reference to time. They were aided by a special formulation of physics known as 'shape dynamics'. Here, it is only the shape of a configuration of particles that is





**“The key feature of the model is that every single solution has two oppositely pointing arrows of time”**

Dr Julian Barbour from the University of Oxford on the arrow of time



Dr Julian Barbour (left) carried out the simulations of 1,000 particles, which suggested another universe

important rather than their absolute separation. In shape dynamics, the ratio of the greatest distance between particles to the smallest can be taken as a measure of complexity.

Barbour's team found that, in pretty much every starting configuration, the cluster went through a state of maximum compactness and minimum complexity, which they associated with the Big Bang. Crucially, from this state, the collection of particles could evolve in two possible ways. “The key feature of the model



## TIME TRAVELLERS

If the Universe ever contracts to a point, it could explain the mystery of dark matter

IF THE REASON things get more disordered is that the Big Bang was in an ordered state, then this leads to a conclusion: cups break and coffee grows cold because distant galaxies are flying away from us in the aftermath of the Big Bang. It is the ultimate connection between the everyday and the cosmic.

So what would happen if cosmic expansion were to one day run out of steam, and the Universe started contracting down to a Big Crunch? The answer is that the Universe, rather than getting more disordered, would get more ordered. In such a circumstance, as pointed out by Thomas Gold of Cornell University in 1958, time would run backwards.

This has prompted an outrageous suggestion for the identity of the Universe's dark matter. Dark matter outweighs the visible stars and galaxies by a factor of about six and reveals itself through its gravitational tug on the visible stuff. In 2000, Lawrence Schulman of Clarkson University in New York showed in a computer simulation that stuff with a normal arrow of time could co-exist with stuff with backward arrow. Just as stuff with a normal arrow of time can survive into the contraction phase of the Universe, reverse-time stuff from the contraction phase can survive into our phase.

What would this stuff look like? If the Universe ever makes the transition from expansion to contraction it is likely to happen at least 100 billion years in the future. By this time, most of the stars will have burnt out. So any relics from the future surviving into our expanding Universe will give out no light. They will appear, according to Schulman, just like dark matter!



After the Big Bang, the Universe started expanding and is getting more disordered. If it contracts in a Big Crunch, time would run backwards



→ is that every single solution has two oppositely pointing arrows of time,” says Barbour. “This is an entirely new result,” he explains. “All other proposed solutions for the existence of an arrow of time of which I am aware require special initial, final or two-time conditions to be added to the law.”

### THE OTHER SIDE

This research suggests that we live in one Universe, but there is another ‘on the other side of the Big Bang’ where time goes backwards relative to us. In this picture, the Big Bang is not the beginning of the Universe, as everyone imagined, but merely the mid-point in its life. The doppelgänger universe

## ORDER OR DISORDER?

Some key laws of physics can all be explained by a smashed mug

HOW DO FUNDAMENTAL laws that make no distinction between processes happening in one direction of time compared to another result in an everyday world where things happen in only one direction? The answer was discovered by the 19th Century physicist Ludwig Boltzmann.

Imagine a mug. There is only one way it can be intact, but there are a huge number of ways it can be broken. For instance, it can be in one big fragment and 10 smaller fragments, or two big fragments and seven smaller fragments, or two big fragments and dozens of dust-sized fragments. And so on. Now, if all possibilities are equally likely, it is overwhelmingly probable that the mug will go from being intact to being broken. It is not impossible that the broken fragments will leap back together to make an intact mug, but it's so unlikely that you would probably have to wait many times the current age of the Universe to see it happen. What characterises all the changes we see around us – from mugs breaking to castles crumbling and people growing old – is a transition from order to disorder. It is this transition which sets the direction of the thermodynamic arrow of time. In physics, disorder goes by the technical name of ‘entropy’. And one of the most famous laws in physics – the Second Law of Thermodynamics – says that “entropy never decreases”. These words are even inscribed on Boltzmann's headstone in Vienna.

It is highly unlikely that these pieces will jump back together again... but it's not impossible



Above: The way particles interact with one another was used to show that there could be two universes





## “This is an important step forward in our understanding of the time asymmetry of the Universe”

Dr Lee Smolin of Ontario's Perimeter Institute discusses Barbour's research



will appear to its inhabitants just as our expanding Universe appears to us, though with different galaxies and stars. The expectation might be that if we could see our twin universe, everything would be going backwards – like a film in reverse. But Barbour says it's impossible to say if this would be the case. “Our model is very simple and we would have to ‘add’ light so that observations can be made and questions like this answered.”

In Barbour's team's scenario, the law of gravity both imposes an arrow of time and doesn't. Although the inhabitants of each universe experience an arrow of time, the two arrows are opposite and cancel each other out overall. The source of the direction of time appears to be the law of gravity. This is very unexpected because the law

of gravity is time symmetric. “This feature has been sitting [unnoticed] inside Newtonian gravity ever since the first evidence for it was discovered by [Joseph-Louis] Lagrange in 1772!” states Barbour.

“This is important in our understanding of the time asymmetry of the Universe,” says Dr Lee Smolin of the Perimeter Institute. “I don't think it's the whole story. But it's a major insight.”

Barbour's model is a simple one that employs only Newtonian gravity. However, our Universe is orchestrated not by Newtonian gravity but by Einstein's more complicated General Theory of Relativity. Nevertheless, the physicists say that the features of Newtonian gravity which lead to their result are also present in Einstein's theory.

Barbour cautions that all his team has shown is that there's a gravitational arrow of time – that is, a direction of time naturally emerges in a system subject to Newtonian gravity. He believes, however, that it will be possible to show that the “thermodynamic arrow of time” – which governs everyday life and causes cups to break and people to grow old – is a natural consequence of the gravitational arrow of time. Watch this space. ■

MARCUS CHOWN is a science writer and broadcaster whose most recent book is *What A Wonderful World*



# THE LON

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TO ARRIVE AT CERES THIS MONTH.  
**COLIN STUART** REVEALS HOW OUR  
UNDERSTANDING OF THIS INTRIGUING  
DWARF PLANET HAS EVOLVED OVER TIME



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PICTURE THE SCENE: Italy, 1 January 1801. Most of the population are ringing in the new year, but Giuseppe Piazzi is scanning the skies with a telescope.

For the previous few decades, astronomers had noticed a sizeable gap in the Solar System between the orbits of Mars and Jupiter. Some had even predicted a missing planet in the region.

That night, Piazzi found it. Our neighbourhood's new addition was christened Ceres, after the goddess of agriculture. The number of known planets nudged up by one – at least temporarily.

At 950km across, and sitting 2.8 times further away from the Sun than the Earth, today we know that Ceres is the largest body in the asteroid belt – the group of small, rocky objects

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The Delta II rocket launched the Dawn spacecraft in September 2007

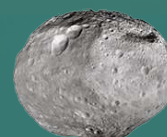


➡ tumbling around the Sun between the inner and outer planets. Ceres makes up around 25 per cent of the entire mass of the belt. Even today, the debate still rumbles over what to call it. After Piazzi's discovery, it was labelled by some as a fully fledged planet. It remained that way in a number of scholarly texts for over 50 years. It then spent the 20th Century as simply the largest asteroid, and is still considered one today. In 2006 came yet another revision. The decision by the International Astronomical Union that saw Pluto demoted from a planet to a dwarf planet saw Ceres gain the same status. Ceres remains the only dwarf planet in the inner Solar System – the rest orbit further out than Pluto.

Above: In this artist's impression, Ceres is seen in the foreground, looking towards the Sun and the inner planets

## CLASS WARS

It is easy to see why Ceres and its flip-flopping classification continues to attract attention from astronomers: its true nature needs nailing down once and for all. Until recently, our best images of Ceres came from the Hubble Space Telescope. Over 200 images were snapped



## VESTA

Dawn visited this asteroid before continuing its mission to Ceres

VESTA IS BOTH the second and third biggest asteroid, depending on how you classify size. At 525km in diameter, it is smaller than Ceres and Pallas. However, only Ceres is heavier.

Vesta was detected on 29 March 1807 by Heinrich Olbers, almost five years to the day after he discovered Pallas and six years after Piazzi spotted Ceres.

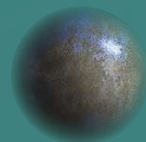
Vesta's surface sports two enormous craters named Rheasilvia and Veneneia. The former covers 95 per cent of the southern pole and takes its

name from the mother of Rome's founders, Romulus and Remus.

As well as craters, the surface of Rheasilvia features long troughs. The largest – Divalia Fossa – measures 465km, which is longer than the Grand Canyon.

Vesta is one of only five Solar System bodies that we have samples of here on Earth. These arrived via meteorites. The others are from Mars (meteorites) and missions to the Moon, the comet Wild 2 and the Itokawa asteroid.





## CERES

The Dawn mission should help clear up this dwarf planet's identity crisis

CERES IS THE smallest of five currently recognised dwarf planets. The others, from biggest to smallest, are Eris, Pluto, Makemake and Haumea.

A total of 24 astronomers (known as the 'celestial police') were searching between Mars and Jupiter for planets at the turn of the 19th Century. But it was Giuseppe Piazzi, not one of them, who found Ceres in 1801.

Dawn will orbit Ceres at a height of 5,900km. After five

months it will be lowered to 1,300km, then drop to 700km after a further five months.

Being small, Ceres's gravity is only 3 per cent of Earth's. Such low gravity makes it an ideal target for human space exploration as it is easy to take off again from its surface.

Ceres is located almost three times further away from the Sun than us, so it will take over 20 minutes for data from the dwarf planet to be relayed to Earth.

in an observing run between December 2003 and January 2004. The photos revealed an almost perfectly round, planetesque form – strikingly different from the asteroids with their jagged, irregular shapes. From its density and rotation rate it seemed plausible that, like a rocky planet, Ceres has layers. These constitute a rocky core, an icy mantle and an outer crust. The debate intensified.

The view from Hubble was intriguing, but could only take us so far. "Hubble's resolution is good, but it wasn't telling us everything we wanted to know," says Dr Carol Raymond, from NASA's Jet Propulsion Laboratory in California. Enter NASA's Dawn mission, for which Raymond is deputy principal investigator.

Dawn was launched in September 2007. By July 2011 it had reached Vesta, which is one of Ceres's large neighbours in the asteroid belt. It spent over a year in situ before departing in September 2012 with a course set for Ceres. It is the first craft designed to go into orbit around two Solar System bodies. Earlier this year, on 25 January, it edged close enough to Ceres for its cameras to exceed the clarity of

**"Planetary scientists generally think the planets were made out of smaller pieces. Is Ceres one of those building blocks?"**



Prof Christopher Russell is the principal investigator of the Dawn mission

Hubble's view for the first time. The mission plan was for it to enter into orbit around Ceres on 6 March 2015. Once there, it is set to spend almost a year trying to unlock its secrets.

### EARLY ORIGINS

As Ceres is such a unique object in the asteroid belt, one of the main goals is to work out its origins. One theory is that there were once many more objects like it, but over time they came together under gravity to form the rocky inner planets. Ceres was left out in the cold.

"Planetary scientists generally think the planets were made out of smaller pieces. Is Ceres one of those building blocks?" asks Dawn's principal investigator Prof Christopher Russell.

A more extreme option is being considered by some astronomers: Ceres is an imposter. The suggestion is that its uniqueness in the asteroid belt is because it didn't actually form there. Instead, they say, it began life out beyond Neptune in the Kuiper Belt – the same region of the outer Solar System in which





# DAWN SPACECRAFT

The craft is full of innovative tech to help it complete the mission to Ceres

THE DAWN MISSION is part of NASA's Discovery Program, which seeks to unlock the mysteries of our Solar System. The programme launches lots of smaller space trips to work in harmony with NASA's larger and more expensive 'flagship' missions. Dawn combines cutting-edge technology from other missions with spare parts and apparatus from earlier space trips.

1

## Star tracker

Dawn is able to orientate itself in space by using its two star trackers to keep watch on its position relative to fixed stars

2

## Cameras

Two 5.5kg cameras will snap close-up images of Ceres throughout the mission. The images will then be sent to Earth

3

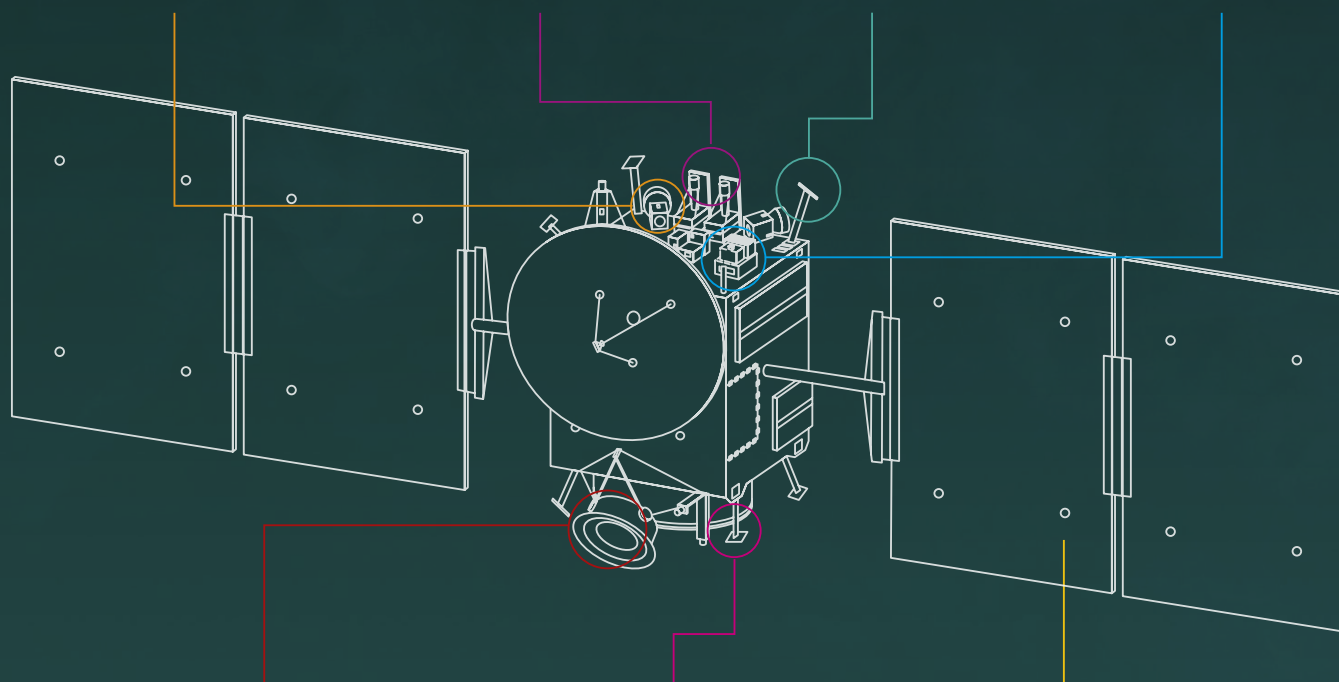
## Spectrometer

By gathering sunlight reflected by Ceres, scientists can calculate various values such as its surface temperature

4

## Gamma ray and neutron detector

This can help determine which elements comprise the surface of Ceres



5

## Ion thruster (1 of 3)

Three high-tech ion thrust units allow for greater manoeuvrability. Dawn has been able to visit Vesta and Ceres in one mission

6

## Antennas

The Dawn spacecraft has four antennas which can be used to communicate with Earth. The longest is 1.52m in length

7

## Solar panels

The ion thrusters are powered by energy gathered through Dawn's solar panels. When extended they make the probe almost 20m wide



## "The Herschel Space Telescope spied a cloud of water vapour around the dwarf planet"

Pluto resides – before drifting to its current location. That would mean Ceres and its dwarf planet cousins have more in common than just a name.

So which is it? Some clues have already been gleaned from Dawn's initial stop at Vesta. "We chose Vesta because it was thought to be the parent body of the HED [howardite-eucrite-diogenite] meteorites which are very ubiquitous in our collection," says Raymond. Chemical analysis using Dawn's instruments confirmed that suspicion. In situ measurements of Vesta were conducted alongside detailed lab studies of the HED meteorites. The results pointed to a swift beginning. "It seems Vesta formed very quickly, perhaps within the first million years of the Solar System," says Raymond.

The key is a radioactive isotope of aluminium, known as aluminium-26. This isotope is known to have been present in the early Solar System, but decays over time. As Vesta formed early, it was able to gather up a significant amount of aluminium-26. The decay happened inside the asteroid, and the heat produced helped govern its geology. By comparing the structures of Vesta and Ceres, it should be possible to estimate when the latter formed. The older it is, the more likely it formed in its current location and not in the outer Solar System.

### WATER PROBLEM

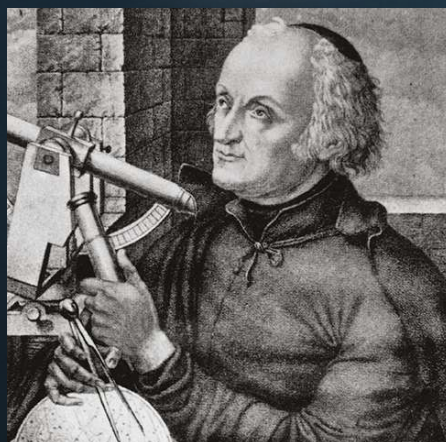
Another important indicator is the movement of water, or lack of it. From measurements of its density, it is thought



Could the white spot on Ceres be a geyser?



From left: Earth, Ceres and the Moon



Italian astronomer Giuseppe Piazzi discovered Ceres in 1801

that H<sub>2</sub>O accounts for around 30 per cent of Ceres's mass. It is likely that in the past some of this water was liquid (perhaps heated by decaying aluminium). As this liquid moved around, it would have come into contact with layers of silicate material and would have altered them chemically. The extent to which this happened depends on where Ceres formed. If it formed in the colder, outer Solar System, the frigid temperatures would have meant the water was more restricted. That would lead to fewer signs of interaction between water and rock.

Wherever Ceres came from, there are recent clues that not all of its water is constantly frozen. In early 2014, the Herschel Space Telescope spied a cloud of water vapour around the dwarf planet. It was the first time that water had been found in the asteroid belt. And wherever there is liquid water, thoughts inevitably turn to the possibility of life. A tantalising clue to the possible source of that water came in January this year as Dawn began its approach to Ceres. Images from the probe revealed a white spot on its surface. The same spot appeared in the Hubble

images over a decade ago. Some researchers have suggested it could be a geyser that is shooting jets of water into space as heat from the Sun warms the ice. That would make it similar to Saturn's moon Enceladus, which is known to be spewing water and is a heralded place to look for life in our Solar System.

So the stakes are high. Depending on what Dawn finds, we could look back at its arrival at Ceres as the first time the asteroid belt became a viable place to search for extraterrestrial life. This year could be a watershed moment in our understanding of planets. Not only is Dawn exploring Ceres, but later this year NASA's New Horizons mission will arrive at Pluto. "We'll start to get a much more nuanced view of the evolution of bodies in the Solar System," says Raymond. "Rather than starting with stuff and ending up as a planet, we're starting to see it more as a spectrum of stages in-between."

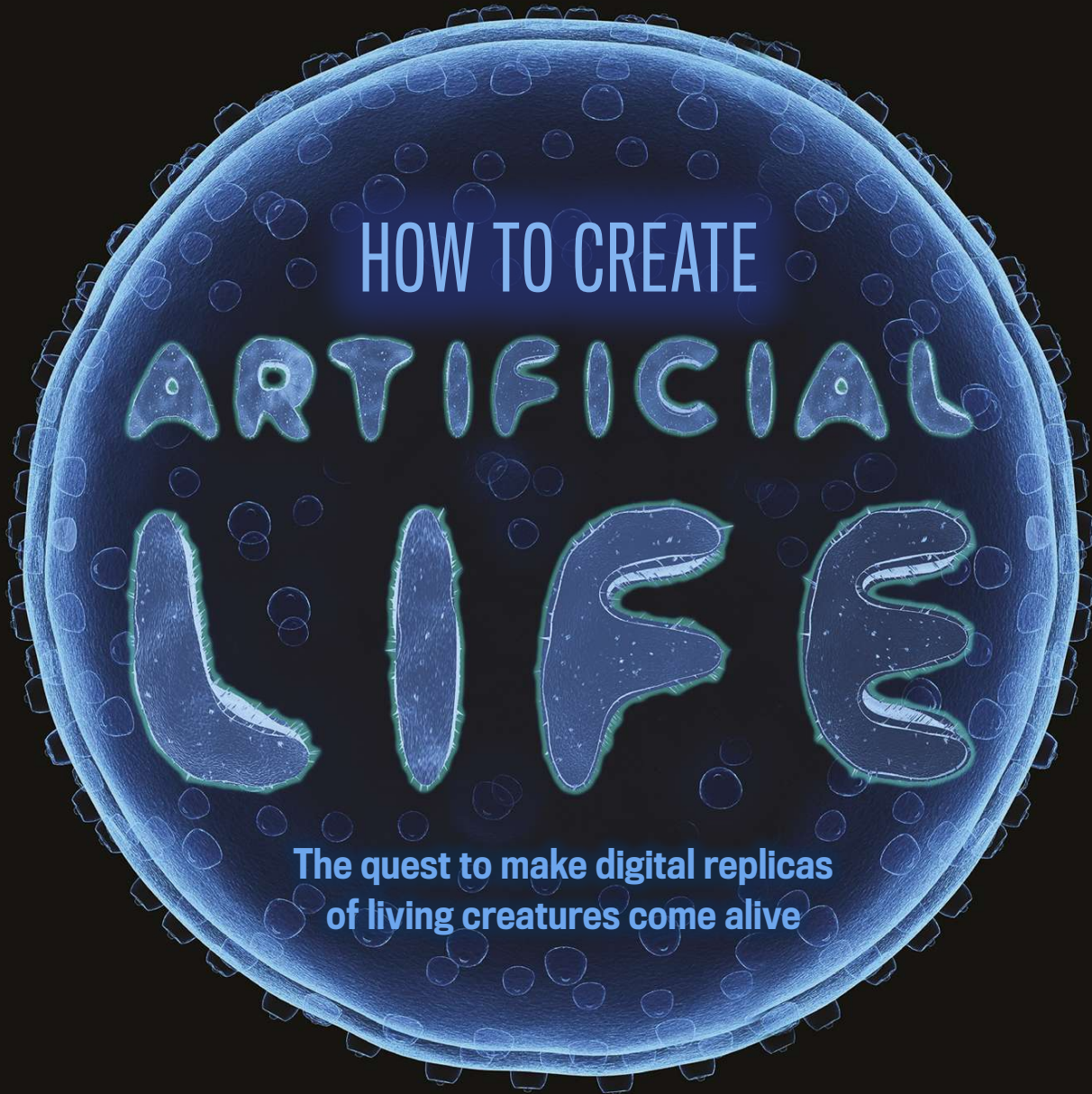
We'll soon know how Ceres and Pluto fit into that picture. What's certain is that the dwarf planet debate is far from over. ■

COLIN STUART is an astronomy writer and co-author of *The Big Questions In Science*

**BBC ONE** Don't miss **Stargazing Live** with Prof Brian Cox, Dara O'Brian and Liz Bonnin on 18-20 March



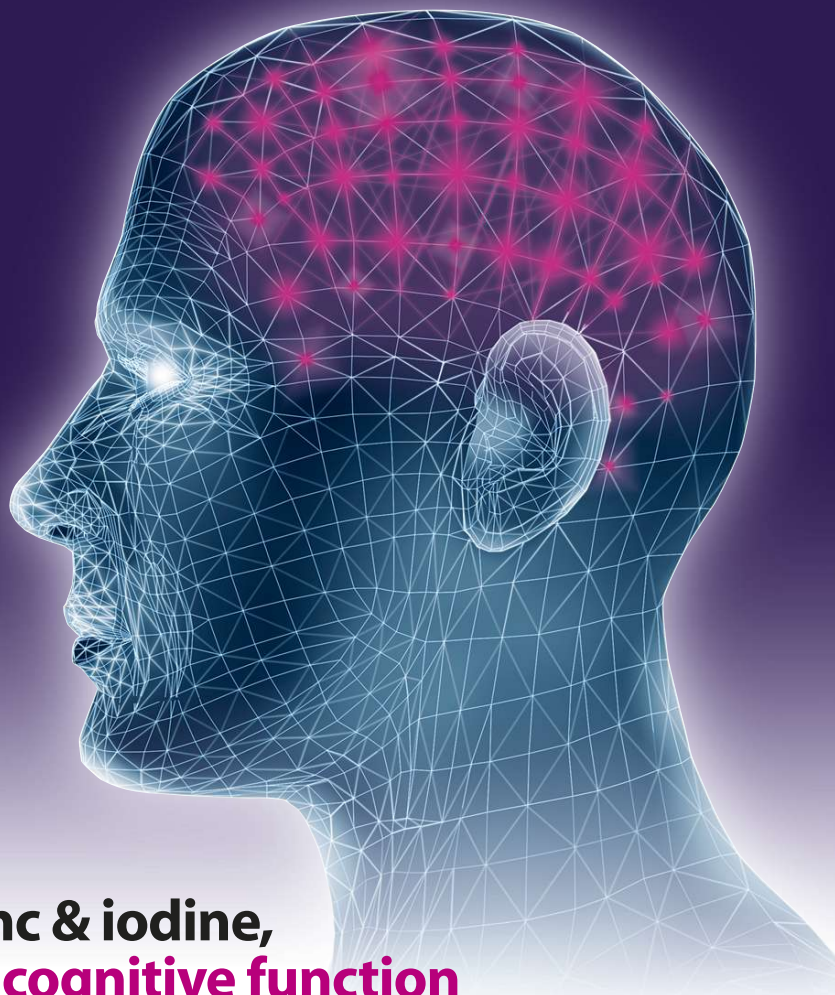
# NEXT MONTH



**Don't miss our May issue, on sale 2 April 2015**



# Feed your mind



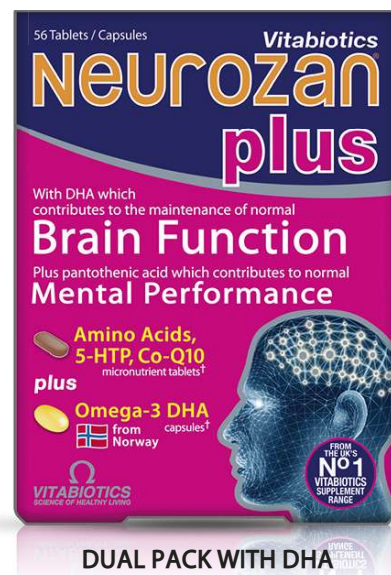
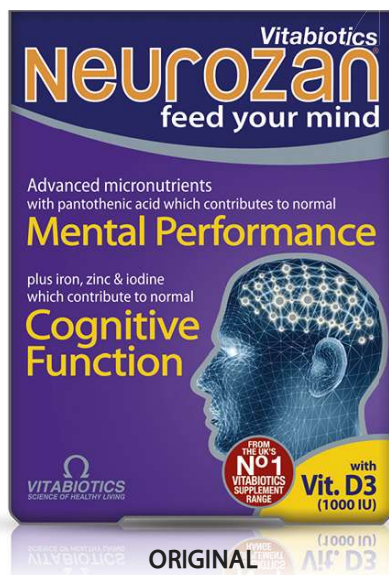
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## Galloway Forest Park

home to the UK's first  
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# Dark sky at night, stargazer's delight

**See the wonders of the universe at the UK's first dark sky park.**

Home to some of the darkest skies in Europe, the **Galloway Forest Dark Sky Park** is the perfect winter destination for an exceptional view of our celestial neighbours.

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A close-up portrait of Edzard Ernst, an older man with a mustache and blue eyes, wearing a dark suit, striped shirt, and patterned tie. He is looking slightly to the left with a thoughtful expression. The background is blurred, showing warm, golden light.

INTERVIEW

# AN ALTERNATIVE VIEW

**Edzard Ernst** has published a book about his career as an investigator of alternative medicine. He tells **Graham Southorn** about his life and work...



### How would you define alternative medicine?

There is not a good definition because it is an umbrella term for lots of treatments that have very little to do with each other. I think of it as anything outside mainstream medicine, except for experimental treatments such as high-tech cancer therapies.

### You were Chair in Complementary Medicine at the University of Exeter - what did your job involve?

It was entirely research-based – we did rigorous research into the ethics, safety and cost effectiveness of these [alternative] treatments. We also wanted to further analytical and critical thinking in this area, because I thought that was badly needed.

### Did you encounter resistance?

I quickly realised that alternative practitioners weren't enchanted by my mission statement. They see themselves as anti-establishment and they don't like science. I'm a conventional doctor by training, so there were tensions, and some made my work difficult. But for the first 10 years or so, it went swimmingly.

### What was your biggest achievement?

One is that, paradoxically, I gave a lot of credibility to the field of alternative medicine. It became something that even sceptics would consider when they saw there was research going on that was truly questioning, rather than trying to prove hypotheses. The other is that we produced a lot of results. We published over 1,000 papers, 40 clinical trials and 300 meta-analyses. Even by producing negative results I was doing something positive. I was telling people, "You can keep your money for this remedy and look for something that's actually helpful for treating your symptoms."

### Are any alternative medicines effective?

Yes – the area where we found most of the positive results was herbal

medicine. Lots of our drugs originate from the plant kingdom, so it's not really surprising. The best example within that realm is St John's wort, which is at least as effective as conventional treatments for mild-to-moderate depression. This is just one of several examples. I was once called a "quackbuster" in *The Times*, and that annoyed me a bit. So I published an article in the *British Journal Of General Practice* covering about 20 treatments which, according to our studies, are worth having on the NHS.

### What's the strangest therapy you've come across?

If you locked up 10 intelligent people in a room and said "I will only let you out once you have come up with the oddest therapeutic concept you can possibly imagine," you couldn't beat homeopathy. It's just one of the oddest things to believe

## "St John's wort is at least as effective as conventional treatments for mild-to-moderate depression"

that like should cure like, and that diluting a drug makes it more effective. Spiritual healing – healing with some sort of divine energy channeled into the body of the patient – is just as odd. And there's reflexology, which assumes that there's a map on the soles of your feet representing the organs of your body, and that by pressing on certain spots you can influence the function of these organs.

### How important is the placebo effect?

It explains why these treatments are apparently so effective. People who use homeopathy are not stupid. They perceive some benefit from it – people have the expectation of getting better and therefore they do get better. If a patient is suffering from a cold and I give them a homeopathic placebo, that patient might indeed benefit. But if I give that patient my understanding, empathy and time plus something that

actually worked, like Ibuprofen, the patient benefits from the placebo effect plus the specific effect of the Ibuprofen. In other words, just giving a placebo is cheating the patient.

### What would your advice be to someone who is considering alternative medicine treatment?

It's not very prudent to generalise – it depends on what condition that person wants to treat and what treatment he or she is proposing to use. But as a rule of thumb, if it sounds too good to be true, it probably is.

### Should there be more research into alternative medicine, given that £1.6bn is spent on it a year?

I think that estimate of £1.6 billion is more than 10 years old! We spend all this money on treatments and very little on research so, yes, some that are biologically plausible should be better researched. But there are others, like homeopathy, where the basics are totally implausible. The evidence, despite 200 years of research, is not good enough to invest in further studies. With herbal remedies and perhaps even acupuncture, further research might be quite useful.

### So acupuncture works?

Acupuncture is interesting and the data is still highly conflicting, but it might be useful for certain types of pain. Even the NICE (National Institute for Health and Care Excellence) guidelines recommend it for the treatment of chronic back pain, which indicates that the evidence is at least promising. Further research is needed to determine whether it is entirely reliant on the placebo effect.

### What are you working on now?

I give lectures, I write a blog at edzardernst.com and I've just started on my next book with a co-author, which will focus on homeopathy. ■

EDZARD ERNST is the author of *A Scientist in Wonderland* (£14.95, Imprint Academic)

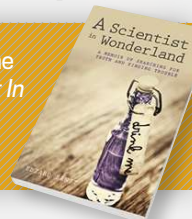


PHOTO: HENRIK EVERTSSON



# DROWNING IN PLASTIC


More plastic than ever is finding its way into our seas, and a lot is sinking to the bottom. **Hayley Birch** finds out how we can get rid of it

PHOTO: ANGRYSUNBIRD/FLOKOR





**T**HROWAWAY LIVING TOOK off in the second half of the 20th Century. Disposable coffee cups, plastic stirrers and parties where all the plates could be tossed in the bin 'improved' our lives. Global plastic production soared from 1.5 million tonnes in 1950 to nearly 200 million tonnes in 2002. Today, it's reached the 300 million tonne mark.

Reports of ocean garbage patches suggest that much of that plastic eventually ends up in our seas. But the reality is much worse, says Marcus Eriksen, one of the co-founders of 5 Gyres, the organisation that studies plastic pollution in 



→ the seas. “We should look at these not as garbage patches, but as clouds of microplastics in the world’s oceans,” he says.

Microplastics is the technical term for tiny pieces of plastic. These are the remnants of throwaway living that have leaked into every ocean. Take a boat out far enough and you’ll witness – as Eriksen has – bottles, toy figurines, roller balls from underarm deodorants and thousands of plastic sandals all floating around in the sea. But microplastics are so finely shredded by ocean currents that they’re impossible to spot from a boat and are easily mistaken for food by sea creatures.

One of Eriksen’s recent studies, published in December 2014, suggests that at least five trillion pieces of plastic, altogether weighing in at over 268,000 tonnes, are floating around near the surface of the sea. An incredible 92 per cent of the pieces are microplastics. But these numbers don’t tally with the volume of plastic we’re producing. A second study published a week later explains why. While a lot of plastic initially floats, it soon gets clogged up with various kinds of gunk and ends up sinking to the seafloor. Just one handful of deep-sea sediment could contain up to 40 pieces of microplastic. At depth, this stuff is difficult to reach, let alone clean up. Which leaves us with one question: what are we going to do about it?

## ALL AT SEA

A project called The Ocean Cleanup has been testing floating platforms for collecting bigger bits of plastic, but their own feasibility study suggests they cannot deal with microplastics. According to Eriksen, we’ll have to live with what’s already out there. “It’s going to sink, it’s going to get buried, it’s going to fossilise,” he says. “There’s no efficient means to clean up 5km down on the ocean floor.”

No one really knows what damage all that stranded microplastic is doing, but the hope is that once it’s mixed up with the sediment, it’s doing less of it. Yet the clouds of microplastics swirling in the water column pose a problem. The debris is easy for marine life to swallow, but the gunk that the plastics collect – such as pollution and bacteria – are also a threat. Plastics could be accelerating the passage of toxic chemicals into the food chain.

In May 2014, chemist Alexandra Ter Halle joined the Seventh Continent Expedition with the aim of analysing the gunk. After two days at sea, the boat was surrounded by thousands of small pieces of plastic.



The Seventh Continent Expedition with some of the rubbish they recovered



Ocean currents shred plastic into fine strands that are difficult to trace and even harder to clean up

**“The difficulty is that there are so many plastics, of different colours, shapes and compositions”**



Alexandra Ter Halle, from the Seventh Continent Expedition



A trash boom on Ballona Creek in Los Angeles catches plastic rubbish



# ROGUES' GALLERY

The plentiful plastics in our seas



Sample of ocean water with visible particles of coloured plastic



The Seventh Continent Expedition found some huge plastic items.



## NURDLES

Millimetre-sized plastic pellets used for making plastic products are frequently spilled into the oceans during shipping



## FISHING GEAR

Buoys and nets are long-lasting and common 'big plastic' finds. Animals often get entangled in them – this is known as 'ghost fishing'



## MICROBEADS

Tiny beads used in toiletries are too small to filter from water. They enter the food chain when eaten by animals



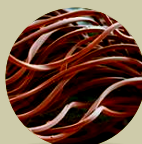
## SINGLE-USE ITEMS

Plastic bags, cups, bottles and forks are often not recycled and eventually end up in the sea



## SHIPPING WASTE

Cargo ships dump – or lose – millions of tonnes of waste every year



## FABRIC FIBRES

Washing machines send synthetic clothing fibres, such as polyester, into water systems



Strands of microplastics found during the Seventh Continent Expedition



Sargassum seaweed taken from the ocean - tiny plastic pieces can be seen

Ter Halle collected samples and is now analysing her data back at Paul Sabatier University in Toulouse, France. She is trying to work out why some plastics attract pollution as they age. "The difficulty lies in the fact that there are so many plastics, of different colours, shapes and compositions," she says. "It's difficult to extract a trend from all those pieces."

The various types of plastic aren't just a dilemma for scientists; they're also problematic for consumers and recyclers. How many times have you wondered into which box to put a plastic lid or some flimsy bit of packaging, then ended up trashing it because you weren't sure?

## NOTHING NEW

Ter Halle agrees there's no easy way of cleaning up the existing mess. The answer, instead, is prevention. She says that switching to biodegradable plastics could offer part of that solution. While the first generation of biodegradables just broke down into smaller pieces, the second generation may have some utility. Ter Halle suggests that they could, for instance, be handy for shopping bags.

Yet Prof Richard Thompson, a marine biologist at Plymouth University, believes that the very notion of biodegradable plastic is flawed. "The idea that you could build into a plastic some kind of magic so that it would fulfil its life in service without deteriorating and then, the minute it becomes an item of litter, it somehow rapidly and harmlessly degrades... it kind of seems like







PHOTO: 5 GYRES/FICKER X3, OCEAN CLEANUP X2, BETTY

Easter Island has a population of less than 6,000, yet plastic pollution is still found there



The Ocean Cleanup project (top and above) has been testing floating platforms to remove large pieces of plastic

➔ you're aspiring towards the impossible," he says. According to Thompson, another problem with biodegradable plastics is mixing them with other plastics as part of the recycling process. The lifespan of the final recycled product is shorter than a product containing no biodegradable plastic.

## CLOSING THE LOOP

Thompson is one of the authors of the second December 2014 study. Having uncovered the true extent of microplastic pollution in seafloor sediment, he wants to see an end to plastic entering the ocean.

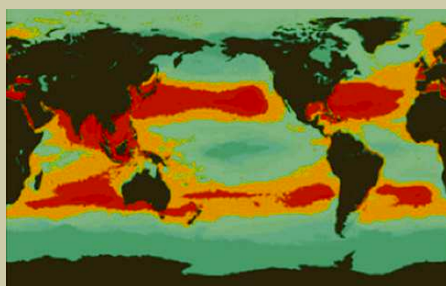
So does he have an answer? He recently attended a workshop in Portugal involving over 50 people from around Europe, including scientists, policymakers and industry types eager to offer ideas for solving the problem. But there was a shortage of cutting-edge solutions. "From my perspective, there was nothing new from any of the participants," he says. "A range of solutions are known to us, but it's more about translating that into action."

One option is banning certain types of plastics for particular applications, such as the plastic microbeads used in facial scrubs and toothpastes. These tiny particles – often measuring less than 1mm

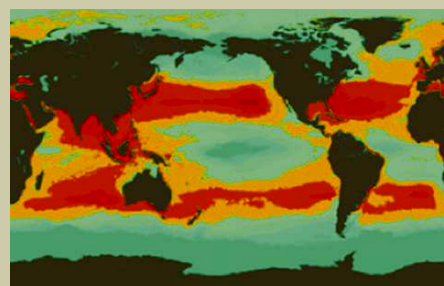


# MAP OF PLASTIC DENSITY

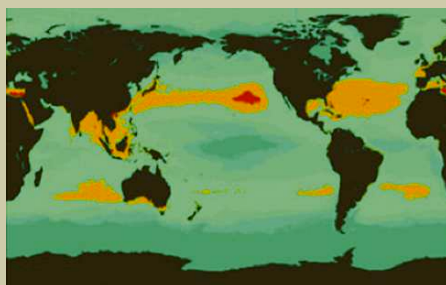
At least five trillion pieces of plastic are floating in our seas. The majority are microplastics measuring under 5mm. These maps show the density of different sized plastics in each square kilometre of the Earth's oceans



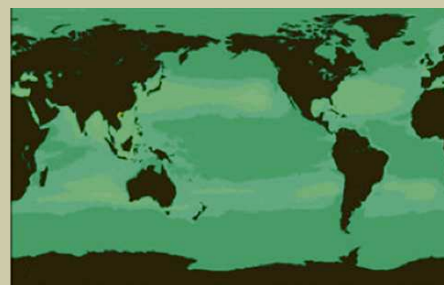
Plastic size: 0.33 - 1.00mm



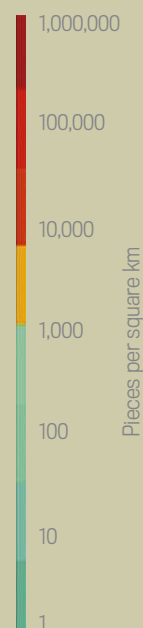
Plastic size: 1.01 - 4.75mm



Plastic size: 4.76 - 200mm



Plastic size: over 200mm



plastic problem in the oceans means solving plastic pollution, full stop.

Thompson gives the example of two empty plastic bottles in his office. Both are made from the same recyclable plastic, but one is worth at least six times less than the other, just because it is red. Clear plastic is far more valuable to a recycler, but manufacturers don't think about this when they're designing their products.

We're still living the throwaway lifestyle we got excited about in the 1950s, but we have to make that our past. ■

**HAYLEY BIRCH** is a science writer and author of *The Big Questions In Science*



– wash straight down the sink and are too small to be filtered out at the waterworks. Thompson and Eriksen are both in favour of this approach, with 5 Gyres supporting a Beat the Microbead campaign that was started by the Plastic Soup Foundation. But it's not enough. Eriksen says that industry has got to be made to take responsibility for the way it uses plastic. "Using it for single-use candy wrappers, [potato] chip bags or stir sticks is just not responsible," he says. "What I suggest is that if the producer or manufacturer

cannot guarantee very efficient recovery of their product, like with some redemption programme or coupon, it had better be environmentally harmless."

To dramatically reduce the amount of plastic accumulating in the oceans, the 'loop' of producing and recycling plastics would have to become a closed one. This means that any material leaving the system as waste would enter it again as a renewable resource. All plastic products would need to be designed with an end-of-life care package. In short, solving the



# Do you want a power-packed memory?

## The Amazing Experience of Robert Heap

"Of course I place you! You're Bob Humphries of Birmingham."

"If I remember correctly — and I *do* remember correctly — John Kershaw, the supermarket man, introduced me to you at the dinner of the Bowls Club three years ago in October."

The assurance of this speaker — in the crowded corridor of the Hotel Piccadilly — compelled me to look at him.

**"He is Dr. Bruno Furst, the most famous memory expert in the world"**

"He is Dr. Bruno Furst, the most famous memory expert in the world," said my friend Keith Clark. "He will show you a lot more wonderful things than that before the evening is over."

And he did.

As we went into the banquet room the toast-master was introducing a long line of guests to Dr. Furst. I got in line, and when it came my turn, Dr. Furst asked, "What are your initials Mr. Heap, your occupation and telephone number?" Why he asked this, I learned later, when he picked out from the crowd the sixty people he had met two hours before and called each by name without a mistake. What's more, he named each person's occupation and telephone number.

**"I can teach you the secret of a good memory in one evening"**

When I met Dr. Furst he rather bowled me over by saying: "There is

nothing miraculous about my remembering anything I want to remember, whether it be names, faces, figures, facts, or something I have read.

"You can do this as easily as I do. Anyone with an average mind can learn quickly to do exactly the same things."

### "Dramatic Improvement"

"I used to be laughed at in the office here about my poor memory and I must admit with a lot of truth. Since I started your Course my memory has improved out of all recognition!"

*Mr. J.W. Sullivan, London S.W.2.*

"That is alright for you, Dr. Furst," I interrupted, "you have given years to it. But how about me?"

"Mr. Heap," he replied, "I can teach you the secret of a good memory in one evening. This is not a guess, because I have done it with thousands of pupils. In the first of twelve simple lessons which I have prepared for home study, I show you the basic principle of my

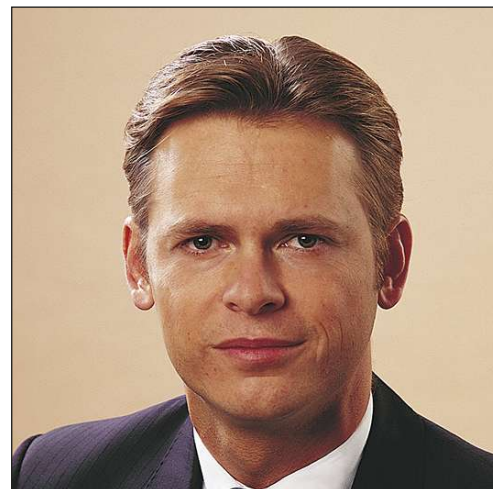
### "Examination Success"

"Excellent examination results have been sound enough proof to carry on adopting your technique for the rest of our lives."

*Mr. S.N. Caldwell, Huddersfield, Yorkshire.*

whole system, and you will find it just like playing a fascinating game. I will prove it to you."

He didn't have to. His Course did; I got it the next day.



When I tackled the first lesson, I was surprised to find I had learned — in about one hour — how to remember a list of one hundred words so that I could call them off forward and back without a single mistake.

Dr Bruno Furst's Course is fantastic! I can rely on my memory now. I can recall the name of anyone I have met before — and I keep getting better. I can remember any figures I wish. Telephone numbers come to mind instantly. What's more my concentration has improved.

### "Best Investment"

"It is the best investment I have ever made. Why is it so cheap? The Course, apart from being so instructive, is easy to read and entertaining."

*Mr. P.R. Jordan, (Ship's Officer)*

My advice to you is don't wait another minute. You could be astounded to learn what a wonderful memory you have got. Your dividends in both business and social advancement could be enormous.

ROBERT HEAP

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# Q&A

## YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



**SUSAN BLACKMORE**

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



**DR ALASTAIR GUNN**

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



**ROBERT MATTHEWS**

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



**GARETH MITCHELL**

Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service



**LUIS VILLAZON**

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO [questions@sciencefocus.com](mailto:questions@sciencefocus.com)

or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

**Q** TIM REES, CANTERBURY

## How can you 3D print a person?

**A** PICTURED HERE IS Andreas Kroker, a customer of German 3D-selfie firm TWINKIND. To produce such a 'mini me', the subject stands in a large 3D scanner. An assembly of high-resolution cameras instantly captures over a hundred images of the person from multiple angles. On the computer, the subject

can be viewed in 3D, rather like in the movie *The Matrix* where Keanu Reeves appears suspended in time. Then comes a process a bit like Photoshopping, but in multiple dimensions. A technician tweaks the digital 3D model to remove any blemishes or errors from the scanning process and to

touch up the image. Then, a specialist industrial grade 3D printer builds up the figure by spreading coloured powder in layers. As it goes along, a precise inkjet applies a binding polymer to hold it all together. The printer combines uncanny accuracy with pretty impressive scale, offering prints up to 35cm tall. **GM**

TWINKIND's 3D printers create perfect replicas of individuals - Andreas Kroker's 'mini me' is on the left



PHOTO: CORBIS



## In Numbers

# 8.8cm

is the length of the longest nose on a living human. The measurement was taken from the bridge to the tip

Q LOUIS ROGERS, BY EMAIL

## Why do we laugh when tickled?

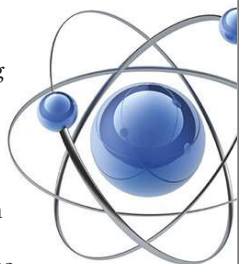
A TICKLING AFFECTS THE same unmyelinated nerve fibres that carry pain signals, and our most ticklish parts are vulnerable spots, such as our neck, abdomen and armpits. Laughing for joy, amusement and tickling all activate brain areas controlling facial and vocal reactions, but only tickling activates the hypothalamus, which is an area that anticipates pain. It's possible that tickling is interpreted as a threat and the laughter is a social signal of submission to prevent us from getting hurt or to defuse a scary situation. **SB**



Q ALEX ROUND, LONDON

## Why is there so much empty space in an atom?

A THE SIMPLE picture of an atom is of electrons whizzing around a central nucleus with nothing in-between, but this is quite misleading. Quantum theory reveals that although the electrons are most likely to be found at specific distances from the nucleus, the supposedly empty space around them is seething with so-called 'virtual particles' constantly popping in and out of existence. **RM**



Q VICKY GILL, CHICHESTER

## What makes us trust some faces over others?

A SIMPLE FACIAL FEATURES will contribute to how much we trust someone. Experiments show that faces with higher inner eyebrows, pronounced cheekbones and a wide chin are judged as more trustworthy. The amygdala, a structure associated with fear and other strong emotions, can respond to a face within 33 milliseconds (three-hundredths of a second).

Volunteers were shown both real and computer-generated faces for such short periods that they did not consciously see them. Nonetheless, they could still make judgments of trustworthiness. This high-speed assessment makes sense in evolutionary terms since detecting threats or judging strangers as dangerous could be crucial to survival. So we should not be surprised if we get a feeling about someone before we've even recognised them. Even so, we should be wary. There is little evidence that people with high cheekbones and eyebrows really are any more honest. **SB**



We wouldn't trust a bloke with half a beard, no matter how high his cheekbones were

Q ALBA LANDRA, OXFORD

## How is the sex of some species determined by temperature?

A TEMPERATURE-DEPENDENT sex determination is seen in most turtles and all crocodiles and alligators. The mechanism isn't well understood, but one piece of the puzzle is the enzyme aromatase, which converts the male hormone testosterone into the female hormone oestrogen. This enzyme reacts very slowly at 25°C but much more quickly at 30°C, so females hatch out of eggs that are incubated at warmer temperatures. Which seems simple, except that in some species the females hatch out of the cooler eggs, and in others, males only hatch from eggs in a middle range of temperatures. **LV**

The sex of many turtle species is determined by the temperature at which the eggs are incubated

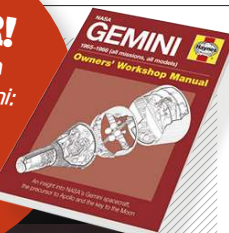




## QUESTION OF THE MONTH

**WINNER!**

Hannah Thompson  
wins a copy of *Gemini:  
Owners' Workshop  
Manual* by David  
Woods (Haynes  
Publishing, £22.99)



Embryonic stem cells can play the  
part of any cell at a moment's notice

**Q** HANNAH THOMPSON, NORTHUMBERLAND

## How do stem cells turn into specific types of cells?

**A** STEM CELLS ARE the ultimate substitutes in the processes of life, able to step in and play the part of specialist cells at a moment's notice. Embryos are full of all-purpose 'pluripotent' stem cells, but we all maintain a population of adult stem cells, whose more limited repertoire is used for repairing damage. Exactly how stem cells do all this is still being worked out. What is known is that they congregate in so-called niches, exposed to proteins that

communicate the condition of tissue around them. At key stages in the development of the embryo, or following disease or injury in adult organisms, these proteins activate the stem cells, switching on the appropriate genes for the specific role they're required to play. Once their mission has been completed – for example, by providing fresh skin cells to repair a wound – the stem cell niche goes back to its monitoring role, awaiting the next call to action. **RM**

**Q** MARK HERBERT, BY EMAIL

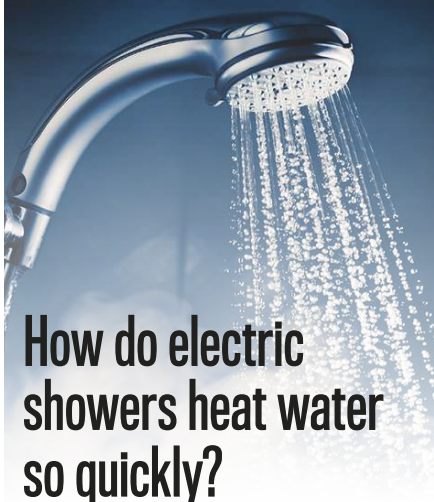
## Are there alternatives to road salt?



'Cheesing' the roads just doesn't have the same ring to it...

**A** SALT IS AN effective de-icer because sodium chloride lowers the freezing point of water and it's fairly cheap. But it's also corrosive and harms plant and aquatic life. In the US, local authorities have experimented with lots of other substances. Sugar beet juice, cheese brine, pig urine and calcium magnesium acetate made from fermented grass work well, but scaling up production to replace the 2 million tonnes of road salt the UK uses every year wouldn't be easy. **LV**

**Q** KIT MCCARTHY, FIFE



## How do electric showers heat water so quickly?

**A** INSIDE THE SHOWER unit, cold water from your mains supply flows into a small plastic tank. Inside the tank is a heating element similar to the one found in a kettle, but four times more powerful at around 11kW. The water heats up almost instantly because only enough to maintain the flow is warmed at a time. There is also a safety cut-out should the water pressure fall too low. **GM**





"Woe is me! Now I'm a millionaire, I no longer enjoy watching the telly"

**Q** CHARLOTTE TAYLOR, BOURNEMOUTH

## Can money bring you happiness?

**A** NO. IN FACT, a 2014 study at the University of California, Berkeley found that being very rich or very poor were both associated with higher levels of mental illness. This doesn't necessarily mean that money (or the lack of it) drives you mad. The study found that those at risk of bipolar disorder and narcissistic personality disorder tended to be more proud of their achievements and more determined to pursue power at the expense of personal relationships. These are people who are more likely to make a lot of money, but if their personality disorder gets the better of them, they can also end up unemployed or bankrupt. Several studies have also looked at the long-term happiness of lottery winners and found that it didn't improve much. Sudden wealth can actually prevent you from enjoying the simple things you used to, like hearing a good joke or watching TV. **LV**

### In Numbers

# 1,013

confirmed exoplanets have been discovered by NASA's Kepler Space Telescope, as of January 2015

**Q** IAN HUTT, LITTLE CHALFONT

## Is the rate of human evolution increasing with population growth?



Has the population boom affected our evolution rate?

**A** LARGER POPULATIONS CREATE more chances for genetic mutations to occur, and this means more variations for natural selection to either favour or weed out. But in big populations, it takes longer for changes to spread. The fastest rate of evolution occurs when a population is split into isolated subgroups that can't interbreed due to geographic or cultural barriers. Travel and communication have

broken down many barriers, so our genes get blended together instead of splitting into subspecies. A 2007 study found that we are evolving about 100 times faster than at any other period in our history. But 'modern' for an evolutionary biologist means the last 5,000 years. It's too soon to tell how our evolution has been affected by the population explosion of the last few centuries. **LV**



Fight! Fight! Fight!

**Q** KEVIN O'BRIEN, CORK, IRELAND

## What makes some drunk people argumentative and troublesome?

**A** IT'S DOWN TO the effect of alcohol on the brain. The prefrontal cortex is important for planning actions, setting priorities and inhibiting impulsive behaviour. Alcohol interferes with this, so people exert poorer judgment and worry less about the effects of their actions. They misinterpret people's intentions and easily lose control of their anger. The variable effects of alcohol on the heartbeat can also be misinterpreted as a danger signal, leading to more anger.

Low levels of serotonin and higher levels of dopamine are also associated with alcohol-induced violence – but not everyone is affected this way. Most at risk are those with poor anger control and little empathy. Expectation and upbringing are important. Adversity in early life can decrease serotonin levels, and drinking when young can damage the brain's frontal lobes. People who see alcohol-fuelled violence as children are more likely to become argumentative and violent when drunk. **SB**





## HOW IT WORKS

# RANGE-R WALL-PENETRATING RADAR

WHEN POLICE OFFICERS pursue suspects to a building, they have no way of knowing what awaits them inside – the suspects could be hiding under the bed or waiting behind the door with a drawn gun.

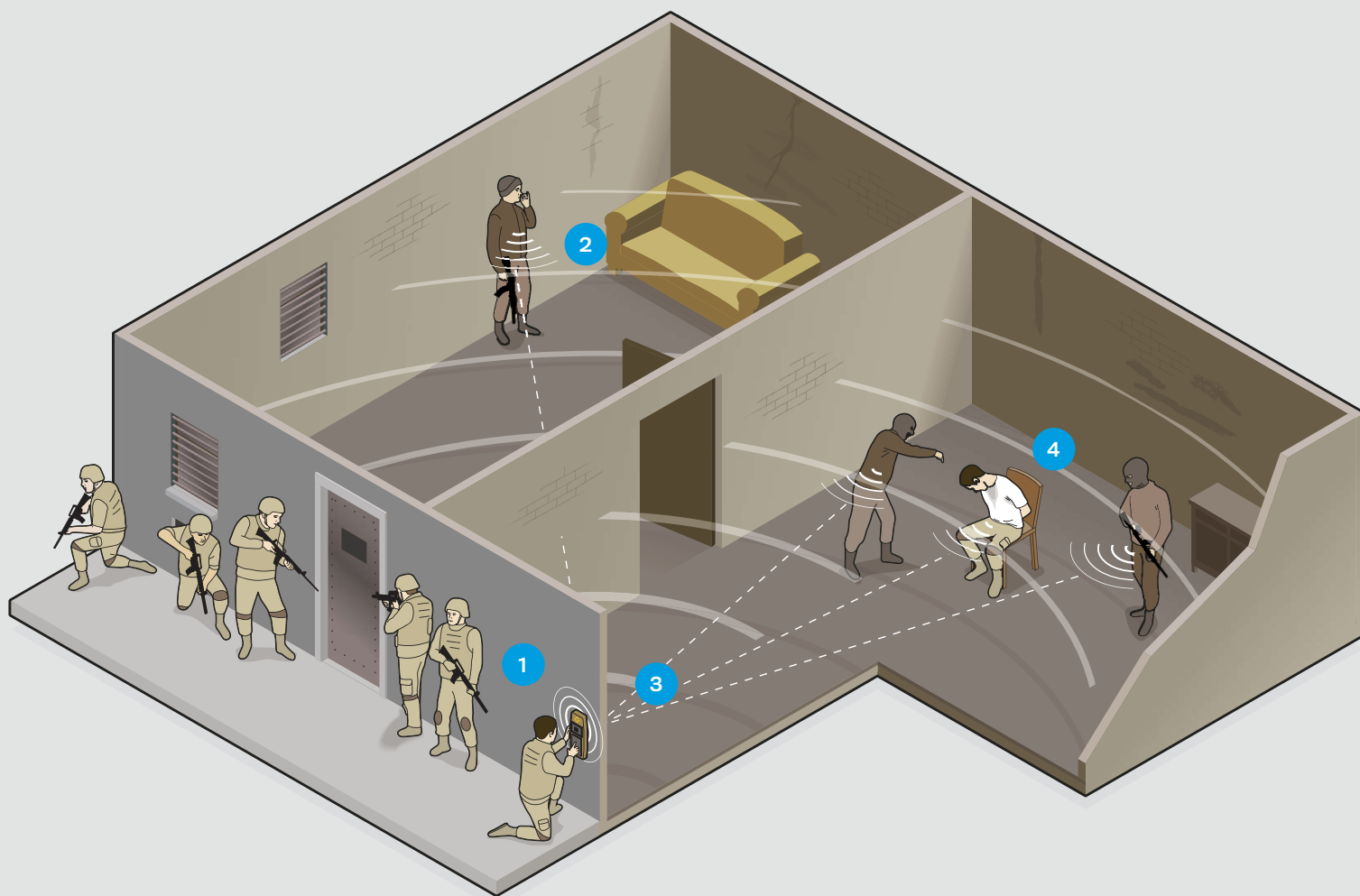
The company L-3 Communications tackles this problem with a device called the Range-R, which is a handheld radar scanner that can peek through walls and report the position of anything moving located inside. When held against a building, the Range-R emits powerful

radar pulses. These can pass through walls made of concrete, brick or wood, but not metal. Obstacles inside the building reflect the waves of radar pulses, which then return back to the Range-R.

Moving 'objects' change the wavelengths of these radio waves, enabling the device to distinguish people from furniture and other items. The Range-R's sensor is so precise that it even detects someone who is merely breathing, from up to 15m away. The device's field of view

covers 160 degrees, allowing it to scan both floors of a two-storey house in seconds. It is also a useful piece of kit for firefighters or search and rescue workers, allowing them to safely check buildings for trapped people.

US authorities like the FBI and the US Marshals have been using the scanner for the past two years, but this has come to light only recently. So far, the US Marshals have spent \$180,000 (£119,000) on the Range-Rs, with each device costing \$6,000 (£3,966).



**1** The lightweight Range-R is held against the wall of a building. It emits radar pulses that can pass through most materials.

**2** The pulses will be reflected by all people and objects in the building. They are analysed as Doppler radar returns.

**3** Within seconds, the Range-R device notifies the user of any people present, and can even detect their locations.

**4** Even if an individual is not moving, they can still be 'seen'. The Range-R can detect someone who is merely breathing.



# TOP TEN

## CIVILIAN AIRCRAFT

(BY MAXIMUM TAKE-OFF WEIGHT, MTOW)

### 1. Antonov An-225

**MTOW:** 640 tonnes  
**First flight:** 21 December 1988  
**Country of origin:** Soviet Union/Ukraine

### 2. Airbus A380-800

**MTOW:** 590 tonnes  
**First flight:** 27 April 2005  
**Country of origin:** Multinational

### 3. Boeing 747-8

**MTOW:** 442 tonnes  
**First flight:** 8 February 2010  
**Country of origin:** USA

### 4. Antonov An-124

**MTOW:** 405 tonnes  
**First flight:** 26 December 1982  
**Country of origin:** Soviet Union

### 5. Boeing 747-400

**MTOW:** 397 tonnes  
**First flight:** 29 April 1988  
**Country of origin:** USA

### 6. Airbus A340-600

**MTOW:** 380 tonnes  
**First flight:** 23 April 2001  
**Country of origin:** Multinational

### 7. Boeing 777-300

**MTOW:** 299 tonnes  
**First flight:** 16 October 1997  
**Country of origin:** USA

### 8. McDonnell Douglas MD-11

**MTOW:** 273 tonnes  
**First flight:** 10 January 1990  
**Country of origin:** USA

### 9. Airbus A350

**MTOW:** 272 tonnes  
**First flight:** 14 June 2013  
**Country of origin:** Multinational

### 10. Ilyushin Il-96

**MTOW:** 270 tonnes  
**First flight:** 28 September 1988  
**Country of origin:** Soviet Union

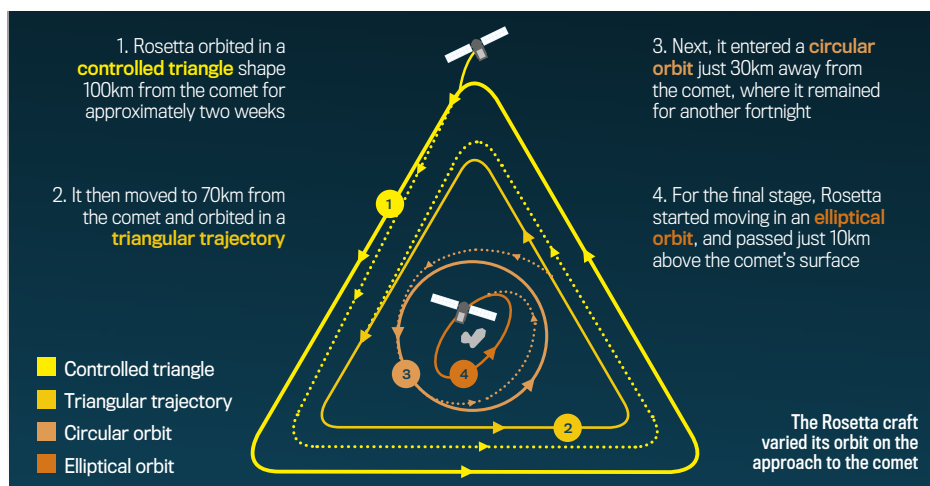
**Q** JIM HAWES, EASTLEIGH

## How does Rosetta stay in orbit?

**A** THE ROSETTA SPACECRAFT is orbiting a very small object in astronomical terms. Comet 67P/Churyumov-Gerasimenko is only 4km in diameter and is irregularly shaped. This means the gravitational field of the comet is both small and irregular itself. To stay in orbit, Rosetta had to approach the comet gingerly. Every few days it fired its thrusters to turn it slightly towards the comet, effectively tracing out a smooth-cornered triangular trajectory around

the comet. The effect of each burn was assessed to determine the extent and direction of the next burn and to help ascertain a more accurate value for the comet's mass and gravitational field.

As time went on, these burns became more predictable and the orbit was lowered to an elliptical shape that passed only 10km above the surface. Rosetta's orbit is called a 'forced' orbit because it is 'powered' and isn't solely dependent on the comet's gravitational field. **AG**



"Oh, I've eaten all the seals. Better p-p-pick up a penguin"

**Q** GRAHAM LANGLEY, BERKSHIRE

## Could we move polar bears to Antarctica to prevent their extinction?

**A** THIS JUST SWAPS one disaster for another. In Antarctica, orcas and leopard seals hunt in the water. None of the other seals and penguins that live there have evolved any defensive behaviours while they are on the ice. If polar bears were suddenly introduced, there would be a brief population boom, followed by a crash, as the local seals and penguins were hunted to extinction. Even though the sea ice in Antarctica is currently growing, climate change is likely to affect the region in ways that will probably be just as bad for polar bears as the shrinking sea ice in the Arctic. **LV**





Although this artwork shows a black hole, astronomers can't actually see them

**Q** MICHAEL GATT, MALTA

## How do astronomers estimate how many solar masses a black hole has?

**A** ASTRONOMERS CAN'T SEE a black hole directly, but they can study the stars that are orbiting around it. By carefully measuring the speed and the radius of these stars' orbits, the astronomers can then use the laws of gravity to deduce the mass of the black hole.

This technique has been applied to stars in orbit around the black hole at the centre of our Milky Way galaxy. It showed the black hole to be about three million times as massive as the Sun.

By averaging the speeds of all the stars orbiting the central black hole in the Andromeda spiral galaxy (our nearest large galactic neighbour), astronomers deduced that it has a mass of about 30 million of our Suns.

Another technique uses a mathematical model of how material spirals into a black hole. By comparing observations of the energy emitted by this material to the model, astronomers can estimate the mass of the black hole. **AG**

**Q** JESSICA MACKIN, BANBRIDGE

## Why don't vultures get food poisoning from eating rotten meat?

**A** THE ACID IN a vulture's stomach is almost 10 times as concentrated as ours. This destroys bacteria so efficiently that vulture droppings are actually more hygienic than the meat they eat! Vultures play an important role in the environment, by reducing the number of contagious bacteria such as botulism, hog cholera and anthrax. But a strong stomach isn't enough by itself, because once bacteria have multiplied in a decaying carcass, they release chemical toxins that aren't destroyed by acid. To counter this, vultures absorb the toxins directly through the lining of their throat and then neutralise them using antibodies present in their blood. **LV**



Yum. Delicious rotten carcass for tea!

**Q** MARK BUCKMASTER, LEICESTER

## Why hasn't evolution sorted out eye defects?

**A** VISION DEFECTS SUCH as myopia (short-sightedness) aren't caused by just one single gene. There's some evidence that short-sighted people have a higher than average IQ, which may be because the same genes affect the eyes and brain. Vision defects often have environmental causes as well. Myopia is more common in people who do a lot of close-up work, have saturated fat in their diet and sleep with a light on. These are all relatively new in our evolutionary history. **LV**



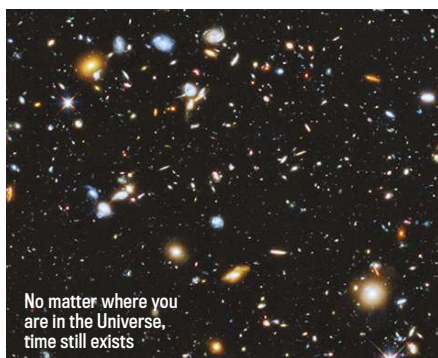
Superman's disguise would be rubbish if no-one wore glasses



Q ALEX SUTHERLAND, BANFFSHIRE

## Does time exist in space?

**A** TIME IS A COMPLEX subject for physics. Einstein showed that time and space are intimately linked and that the progression of time is relative, not absolute. Although there is nothing in physics that says time must flow in a certain direction, scientists generally agree that time is a very real property of the Universe. Our science is thus based on the assumption that the laws of physics, and the passage of time, exist throughout the Universe. **AG**



No matter where you are in the Universe, time still exists

Q HARRY KNOBLAUCH, KERRY, IRELAND

## At what height does a building become a skyscraper?

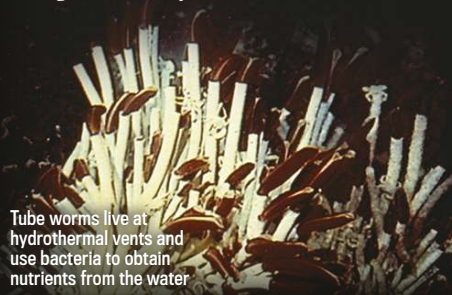
**A** THERE IS NO specific height at which a tall building is classified as a skyscraper. For most engineers, the definition is a tower block of 'considerable height' that has multiple storeys. Structurally, the walls should not be load-bearing but instead hung on a framework of steel girders and usually a central spine. **GM**



Q TERRY HANLOW, BIRMINGHAM

## Could life have originated deep inside Earth?

**A** THE IDEA THAT life could thrive deep below Earth's surface was once regarded as heretical. Lacking any obvious source of energy, such as sunlight, and subjected to intense heat



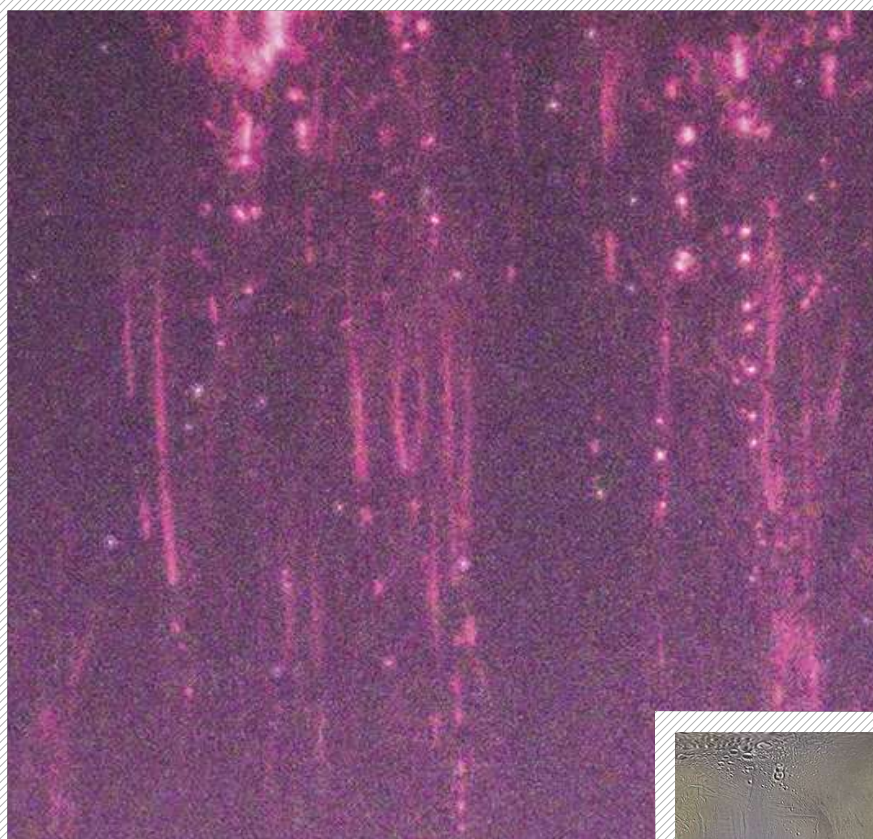
Tube worms live at hydrothermal vents and use bacteria to obtain nutrients from the water

and pressure, subterranean organisms would seem to have little chance of survival. Yet since the 1980s, bacteria, fungi and worm-like creatures have been found lurking kilometres down in mine boreholes and deep sea sediments.

These organisms have extraordinary sources of energy. For example, some bacteria rely on the reactions between water and rocks to get their energy.

Dating techniques suggest bacteria have existed at depths of several kilometres for at least 30 million years. What isn't clear is where they fit in to the history of life on Earth: were they washed down, or are they progenitors of life on the surface? Either way, their existence has boosted hopes for life on Mars. While none has been found on the surface, NASA's Curiosity rover recently detected methane coming from within the planet – which may be the result of subterranean organisms. **RM**

## WHAT IS THIS?



### KNOW THE ANSWER?

Submit your guess now at [sciencefocus.com/qanda/what](http://sciencefocus.com/qanda/what)

### LAST MONTH'S PICTURE

**Matt Mason** correctly guessed one of Saturn's moons, Enceladus



Q PAUL SMITH, FOLKESTONE

## Is it coincidental that the human menstrual cycle is about the same length as the Moon cycle?

**A** CHARLES DARWIN THOUGHT that the 28-day human menstrual cycle was evidence that our ancestors lived on the seashore and needed to synchronise with the tides. The Moon's phase certainly has an effect on the behaviour of many animals. Fiddler crabs are more active at full and new Moons because the tides are higher, so their burrows are uncovered for longer. Gerbils avoid foraging at night during a full Moon, because the extra light makes them more likely to be eaten by owls. But the human menstrual cycle is only the same *length* as the lunar month – it isn't synchronised with a particular phase. One frequently cited study, published in the *American Journal Of Obstetrics And Gynecology* in 1980, found

some evidence of synchronisation, but the effect was very weak. Of the sample of 312 women, 244 had cycles that were longer than 29 days or shorter than 27, and only 70 per cent of the rest actually started their period within two weeks of the full Moon.

If locking our reproductive cycle to the lunar month was advantageous, you might expect other animals to do the same. Orangutans and possums have 28-day cycles, but our closest relatives, the chimpanzees, have 35-day cycles. Non-primate mammals have an oestrous cycle, which works differently to menstruation, but none of them synchronise their reproduction with the phases of the Moon. **LV**



Q CHARLIE WARD, KING'S LYNN

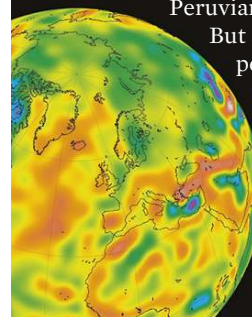
## Does gravity vary across the surface of the Earth?

**A** AS A RULE of thumb, places near the Earth's equator experience lower gravity than those near the poles, through the joint effect of the Earth's spin and equatorial bulge.

Observations by satellites show that gravity is weakest in the

Peruvian mountains.

But at less than 1 per cent below the global average, you'd never be able to tell. **RM**



Purple is where gravity is lowest, moving to blue, green, yellow, red and white (highest)

Q RICHARD O'NEILL, GLASGOW

## Does nasal hair have any useful function?

**A** CERTAINLY! IT'S A filter for dust, pollen, spores, viruses and bacteria. Particles stick to the wet surface of your nose hairs, which prevents them from reaching your lungs and causing infection. Eventually you'll either blow the nasties into a tissue, or swallow them, to be destroyed in your stomach. **LV**



Q GEMMA ROSS, READING

## How does the brain distinguish between good and bad smells?

**A** MOLECULES IN THE air dissolve in mucus inside the nose and are detected by olfactory receptors, which send signals to the brain. In primates, including us, there are two pathways. One goes to the olfactory cortex. The other passes to the hypothalamus, which is involved with emotion, motivation and memory. This part is responsible for whether we like or reject a smell. It may also be why smells and memory have a close association.

Although humans have a comparatively weak sense of smell, it is still important. Day-old babies show expressions of disgust when they smell fish or rotten eggs. Children can distinguish between the smell of their siblings and other children of the same age. A baby recognises its mum's smell and a mother recognises their baby's. Even the humble

fruit fly has complex olfactory processing. It has one system that identifies a smell and another that categorises smells as good or bad. To watch the *Focus* team sampling some of the world's worst smelling foods, visit <http://youtu.be/0rwB2Cw-Pe8> **SB**

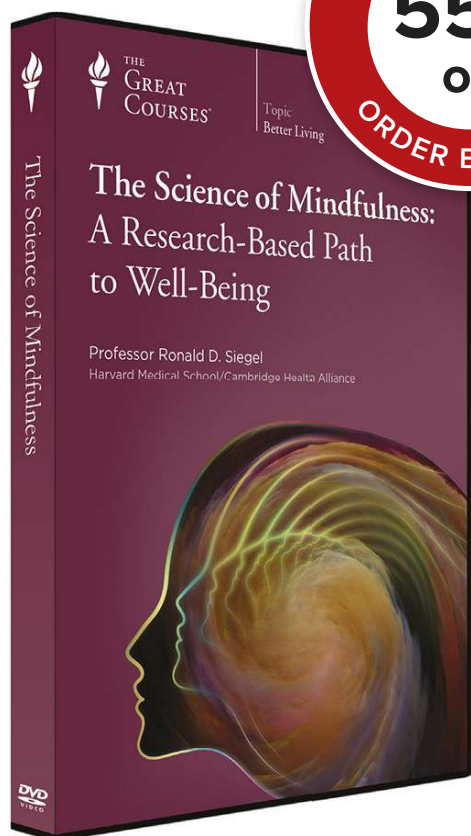


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3. Informal, Formal, and Intensive Practices
4. Who Am I? The Perils of Self
5. Mindfulness or Psychotherapy?
6. Attention and Empathy in Relationships
7. The Science of Compassion and Self-Compassion
8. Tailoring Practices to Fit Changing Needs
9. Modifying Our Brain Function and Structure
10. Solitude—An Antidote to Loneliness
11. Connecting with Children and Adolescents
12. Seeing Sadness and Depression in a New Light
13. Befriending Fear, Worry, and Anxiety
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15. Placebos, Illness, and the Power of Belief
16. Interrupting Addiction and Troublesome Habits
17. Overcoming Traumas Large and Small
18. Groundbreaking Mindfulness Programmes
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# THE FUTURE OF GADGETS

# TECHHUB

EDITED BY DANIEL BENNETT

## THIS MONTH

**BILL THOMPSON**  
Ditch the cash  
p79

**JUST LANDED**  
New Nintendo 3DS  
p80

**ULTIMATE TEST**  
Tough earphones  
p83



## ON THE HORIZON

## HOLOLENS

**Holographic  
computer  
platform**

[microsoft.com/microsoft-hololens](http://microsoft.com/microsoft-hololens)

WORDS: DANIEL BENNETT

**T**HE PHYSICAL AND virtual worlds are about to collide.

Microsoft's latest research project, the HoloLens, wants to liberate your software from the screen and let it roam around in the real world via a pair of specs. Imagine popping on your HoloLens and then building a virtual *Minecraft* castle on your desk. That's the experience it could create.

The potential of the HoloLens doesn't just lie in gaming. The idea is that all the apps that currently sit behind your display could climb out

into the real world. In Microsoft's demo, a designer moulds the curves of a superbike with his hands; a dad gives his daughter virtual instructions to fix her sink; and a scientist explores Mars.

At first sight, the technology seems too fantastical to be real, and it wouldn't be the first time a tech company made promises it couldn't deliver. Closer inspection, however, reveals that the HoloLens simply blends existing technology to create something new.

First, the glasses use a prism projector (like







The HoloLens could allow users to build virtual 3D objects

→ Google Glass) to create images directly in your field of vision. Second, Microsoft's own Kinect tech allows the headset to see, and make sense of, the world around it. Just as with Kinect on the Xbox, it follows your arms and hands, and translates this into instructions to the computer. By pairing these technologies, the HoloLens can recognise a flat surface and create a three-dimensional image in front of you. And then there's the sound.

For a virtual object to feel truly real, it needs to create noise, and that audio has to come from the right direction. The headset is fitted with special earphones and software that can simulate noises in a 3D space. This is crucial for immersion, especially since Microsoft hopes that the HoloLens will be used for simulations.

So far, so sci-fi. But there is a drawback. While all this technology does exist and can be fitted together, it's all rather large. The official imagery shows Microsoft's aspirations for the final product, but the

prototype is very different in reality. The first developers to wear the HoloLens (at Microsoft's secret basement laboratory) described wearing numerous straps, screws, battery packs and even fans that cooled the whole unit down. But every great idea starts with a cobbled-together prototype. Screens, batteries and processors are shrinking by the day, so there's very little to stop Microsoft putting together a finished device – closer to their concept imagery – within the next two years. And there's one very good reason for that.

That reason is Windows 10. Microsoft says it will build HoloLens compatibility into its next big operating system, which is something of a lifeboat for a company that has been losing users for the last few years. On top of that, the head of the project is the same Microsoft employee who delivered the Kinect technology that first blew us away five years ago. There's no reason why they can't do the same with the HoloLens now.



Microsoft's HoloLens concept cleverly blends existing technology

**DANIEL BENNETT** is the reviews editor of *BBC Focus Magazine*

## TECHOMETER

### WHAT'S HOT

#### YOUVIEW

This on-demand TV service pools together catch-up TV from BBC iPlayer, ITV Player, Demand Five and 4oD. Later this year it will be available on Sony internet-connected televisions as a single app. This service, which you can get already via set-top boxes, gathers together all of the week's TV that's online. It then puts it onto your episode programme guide, so you can simply scan over the past week to pick up any shows that you've missed.



### WHAT'S NOT

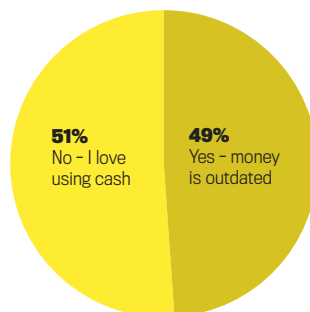
#### KEYLESS CAR ENTRY

Walking up to your car and opening the door without taking out your keys is a neat trick, but it's one that car thieves seem to like too. A report published by London's Metropolitan Police suggests that keyless car theft is on the rise. In the capital, 17 cars are stolen every day without keys. Of these, 70 per cent are models that use keyless car entry. Apparently, the thieves have devised processes that can hack the car's entry system.



### READER POLL

Would you like a cash-free society?





## THE NEXT BIG THING

# A CASH-FREE WORLD

WELL, IT SEEMS that 2015 might be the year that we finally wave goodbye to cash. I already use contactless payment cards much of the time. I'm on the verge of abandoning my Oyster Card, which I use to pay for tubes and buses while travelling around London, since I can now use a contactless debit card instead. I also use my smartphone to pay for stuff – I've installed an app for one well-known coffee chain so that I can accumulate gold stars and get free coffee. And when Apple Pay comes to the UK, I'm sure I'll find myself using it. The days of paying with cash, handing over a note and receiving a pocketful of 'shrapnel' as change are numbered.

I'm not alone in changing my spending habits. The Payments Council, which looks at the whole range of payment services in Britain, is predicting that cashless payments will overtake cash transactions during 2015. And the trend is only going one way – not only in the UK but around the world too.

There are lots of different reasons for the move to cashless payments. One is

simply that the technology is now available to replace cash with other forms of payment, and the banking system likes this. Payment service operators such as Visa and Mastercard would like to see the end of cash, partly because it makes them money but also because they see it as a legacy technology. The CEO of Mastercard, Ajay Banga, calls cash "the dirtiest secret of the modern economy" and says that it is 200 years out of date. Plus, the cost of making coins and notes and moving them around is substantial.

There may also be political pressure to move away from cash. Electronic money expert David Birch argues that the two groups who like cash the most are criminals and tax avoiders, and that replacing cash would increase tax revenues and reduce corruption.

The change isn't just happening in developed countries either. Mobile payment systems like M-Pesa, which started life in Kenya, continue to grow in importance, not least because cash is very inconvenient if you live in a country with poor transport systems and few bank accounts.



As we move away from using cash, we are also going to see big changes in the forms of 'money' that we use to pay for things, or get paid for our work. Peer-to-peer digital currencies like BitCoin, independent of the banking system and the world's governments, continue to attract attention. Even if they won't ever replace the global financial system, they can still serve as an alternative means

of exchange for those who want to avoid the fiat currencies that are created by central banks.

Either way, you might want to hold on to your pennies – they might not be around for long.



**BILL THOMPSON** contributes to [news.bbc.co.uk](http://news.bbc.co.uk) and the BBC World Service

## FROM THE LAB

Gadgets powered by people

### WHAT IS IT?

Scientists at the National University of Singapore have developed a flexible, nano power generator that produces an electric charge when it comes into contact with skin. It is the size of a postage stamp and creates 90V of energy and 0.8 milliwatts of current – enough to run a small wearable.

### HOW DOES IT WORK?

It relies on something called the 'triboelectric effect'. This takes place when a charge builds up between two dissimilar surfaces when they are put in close contact. It is this that causes your hair to stand on end when you rub a balloon against it. The generator collects this electricity to power a small device.

### THIS SOUNDS EXCITING. WHEN CAN I GET ONE?

The team's next goal is to build an activity tracker that is powered by the user's own motion. Perhaps in a couple of years we may see fitness watches that never need to be plugged in, allowing you to take them on holiday without lugging chargers and adaptors along with you.



The generator could lead to fitness monitors that don't need to be charged





# JUST LANDED: NEW NINTENDO 3DS

## GAMES MASTER

It's hard to tell, but this is Nintendo's latest console, the new 3DS. **Daniel Bennett** plays spot the difference

PRICE: FROM £149  
NINTENDO.CO.UK



### What's new about it?

Okay, so the new 3DS doesn't look very different at all from the original. And that's because it's not. There are some additional buttons, including trigger keys on the device's shoulders and a nub that inputs directions. There are also a few improvements under the skin: a more powerful CPU, an infrared face tracker next to the camera and an NFC sensor. The latter works with Nintendo's Amiibos – plastic figurines onto which you save your characters so that you can load them into other people's games.

### So why should I bother?

It might seem like a meagre list of upgrades for a whole new console. Especially when you

look at the kind of leaps other systems make from one generation to another. But there is a good reason for this. The original 3DS was almost the perfect handheld gaming machine. It was simple, offered a richness of games, lasted for days between charges and would survive almost anything a child could throw at it. Why reinvent the wheel?

### What are the improvements?

The new CPU makes everything snappier. The graphics are slightly improved, but there aren't any games out yet that really put this to the test. This isn't a worry, because the console's selling point was never its visuals. The extra buttons are a welcome

addition and, in time, they'll allow for more complex games and boost the system's already impressive library of titles. The new console is even capable of playing games from the original.

The best feature by far is the face tracking. I never bothered with the 3D setting for my original Nintendo 3DS: for it to work, your head had to be perfectly aligned with the console. If you moved either, the 3D illusion was instantly shattered, leaving your eyes to reconcile the blurry image. The new console now knows your head's position and sends separate images to your eyes. The 3D effect is no longer just a gimmick – it's an integral working part of the console.

### Should I buy one?

If you have kids, they're probably going to pester you between now and Christmas for the new 3DS. It's a hard choice. The 3DS hasn't kept pace with the rest of the world. Nintendo doesn't care about screen resolutions, megapixels or processing power, so the new console isn't that different from its predecessor. But what Nintendo has focused on is sheer fun – fixing all the niggles of the original that might have got in the way. It's not the most high-tech piece of kit we've ever tested, but it's certainly one of the best. ■

**DANIEL BENNETT** is reviews editor of *Focus* magazine




**1**

**2**

**3**

**4**

**5**

**6**

# **APPLIANCES OF SCIENCE**

## **1 BETTER WI-FI**

With more and more home appliances getting fitted with Wi-Fi connections, your internet router is becoming as important as your fuse board. Yet most routers are about as user-friendly as a bouncer at 3am. Eero looks to change this with a simple Wi-Fi system that lets you grow your network by adding more boxes. Best of all, it can even self-diagnose problems and repair itself. Nifty.

**Eero**  
\$125 (£82.14) plus P&P,  
eero.com

## **2 BLACK BOX**

NFL players typically endure blows similar to those experienced in a car crash. The majority of these don't cause permanent damage, but there's no system to look out for dangerous hits. Linx IAS uses tech normally used to test bulletproof vests to monitor head impacts in contact sports. The sensor, which slots into a headband, flashes red after a serious impact and can be synced with a smartphone.

**Linx IAS**  
\$199 (£130) plus P&P,  
linxias.com

## **3 GREEN FINGERS**

The Parrot Pot could be the hero that your plants have been waiting for. You tell it what's been planted via the app. Sensors then monitor moisture levels in the soil and release water when it's too dry. Detectors tell you how much fertiliser is present in the soil and the current temperature. And there's even a sunlight sensor that tells you to move the pot if it's not getting enough rays.

**Parrot Pot**  
Price TBC, parrot.com

## **4 CHEFFY GADGET**

To cook meat perfectly, professional chefs tend to cheat. Their secret is a sous-vide machine: a water bath that lets you cook vacuum-packed food slowly and precisely. Usually this kind of cooking requires a big machine, but Anova's precision cooker simply drops into a cooking pot and is controlled via an app that practically takes over the cooking, letting you put your feet up.

**Anova Precision Cooker**  
\$179 (£117.75),  
anovaculinary.com

## **5 SLEEPY HEAD**

You can now add bedding to the list of things that come with Wi-Fi. Sensors in the Luna mattress topper use your heart rate, movement and breathing rate to wake you at your least groggy. It'll even learn what time you head to bed each night and it warms the sheets before you get in. It splits the bed into two zones, so each person can select their own temperature.

**Luna**  
\$199 (£130),  
lunasleep.com

## **6 BREATHE EASY**

Turn your phone into your own breathalyser kit with this keyring. Simply blow into the Breeze and it'll quickly give you a reading with "law enforcement grade accuracy". If you're over the limit, it'll provide you a "Back to Zero" figure that tells you how long you'll have to wait to sober up. It'll even offer suggestions for nearby cab companies and cafes, so you can get home or grab some food.

**Breeze**  
\$99.99 (£66)  
breathometer.com



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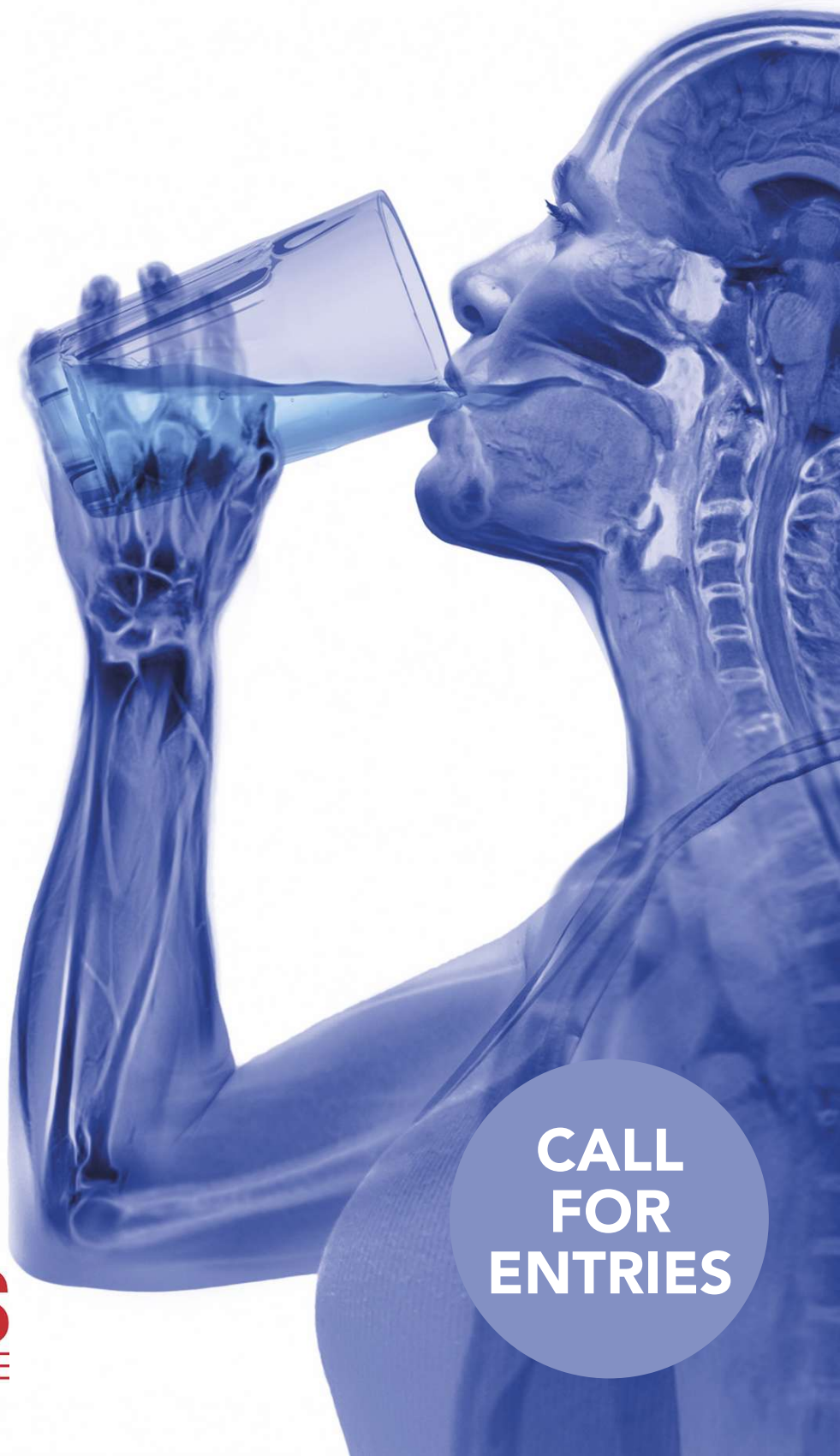
The competition is supported by Siemens.

Visit [www.siemens.co.uk/curiosity-project](http://www.siemens.co.uk/curiosity-project)

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**BBC** **FOCUS**  
MAGAZINE

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ULTIMATE TEST

# SOLID SOUNDS



If you're anything like us, your earphones go wherever you do, so they ought to be built to last. **Russell Deeks** tests the toughest in-ears in town...

**W**HETHER you're a sporty type or just a clumsy commuter, you don't want to spend good money on a pair of earphones only for them to break. So we took four 'rugged' pairs and put them through their paces. In our Snag Test, we caught the cable on

door handles, many times over. In the Jerk Test, we ripped jack from socket as roughly as we could, from every tortuous angle we could think of. The Shower Test is pretty self-explanatory, while our Crunch Test assessed their ability to withstand being trodden on by 13 stone of great lumbering oaf. Turn over to see how they fared...





**SE215  
SHURE**

SHURE HAS A long pedigree when it comes to pro audio equipment. This is evident in the build quality of these earphones, which Shure says are “built to withstand the extremes of on-stage or everyday wear”. They feature a replaceable cable, just in case it decides to break. However, as said cable is very substantial, Kevlar-reinforced and features an L-shaped connector, that’s frankly unlikely to happen.

The SE215 earphones are supplied with a choice of six different sleeves – three in silicone, three in foam – to help you get the best fit, therefore ensuring both optimum sound quality and maximum isolation. A pick for cleaning off any wax build-up is also supplied, as is an oval carry case to keep them safe in your bag or pocket.

As for the sound quality, Shure’s pedigree once again shines through. Mids and highs are clearly defined, and there’s plenty of hefty bass that never sounds muddy or muffled. The stereo imaging could perhaps be a little better, but were we looking at sonic performance alone, Shure would likely be walking away with the gold here.

Sadly, they fell down a little in the toughness stakes. They handled the Jerk, Shower and Snag tests perfectly... but being stepped on was the straw that broke the Shures’ back.



shure.co.uk, £85

**TOUGH  
TESTS**

SNAG TEST: PASSED  
JERK TEST: PASSED  
SHOWER TEST: PASSED  
CRUNCH TEST: FAILED



**ATH-SPORT3  
AUDIO-TECHNICA**

THE ATH-SPORT3 earphones feature an ‘ear-hanger’ design that ensures they’ll stay on your lugholes, and come with seven different sleeves to guarantee they fit nicely. Four of these are in plain silicone and three in ridged ‘active fit’ silicone. The latter are designed to let in more external sound so that they can be worn safely when jogging on city streets, for example. There’s a compact nylon case to keep them safe, too. The cable seems a tad flimsy, but it does feature an L-shaped connector and an attached clothing clip to prevent it from catching on things. Oh, and the earphones are water-resistant to IPX5, which means they’re splash-proof and can be safely used in very humid environments.

This bespectacled, long-haired reviewer found the ear-hanger

design a bit awkward at first, but you soon get used to it, and there’s no faulting their sound. They’re not quite as powerful at the bottom end as the Shures, and are a bit more brash, but the stereo imaging is better. Dramatically panned sounds actually sweep from one side to the other, rather than just suddenly popping up in the other ear. They passed our durability tests with flying colours, too.

All of which is particularly impressive when you look at the low price tag. If you’re on a budget, these are a great choice.



eu.audio-technica.com, £45

**TOUGH  
TESTS**

SNAG TEST: PASSED  
JERK TEST: PASSED  
SHOWER TEST: PASSED  
CRUNCH TEST: PASSED





## SPORT PULSE WIRELESS JABRA

THE HEFTY PRICE tag of these earphones reflects the fact that they're not just earphones. They also feature a built-in heart monitor, which works alongside a dedicated Jabra Sport Life app – or other popular fitness apps such as RunKeeper – on your iOS or Android device.

The Jabra Sports also come with a choice of four sleeves and four different 'ear wings' to help ensure a close, comfortable fit. A no-brainer for sporty types, then? Er, not quite. Maybe I've just got weird ears, but despite trying every possible combination of sleeves and wings and watching a tutorial video on the Jabra website, I couldn't get them to sit comfortably at all. And because they weren't fitting tightly, the sound coming out of them was almost entirely bass-free.

They're not without their good points: Bluetooth pairing is a doddle, with a woman's voice talking you through the process in the earphones themselves (a very snazzy touch), and with a useable range up to around six metres. They also work via NFC, which may be a bonus for some.

The hardshell black and yellow carry case looks really good and feels sturdy, and we couldn't manage to break the earphones even when we subjected them to a simulated downpour. But 'try before you buy' would be our advice here.

■■■■■  
jabra.co.uk, £200

**TOUGH  
TESTS**

SNAG TEST: PASSED  
JERK TEST: PASSED  
SHOWER TEST: PASSED  
CRUNCH TEST: PASSED



## SUPERDARTS TITANIUM ATOMIC FLOYD

THESE ARE THE most expensive earphones in this test, but you certainly feel like you're getting your money's worth. Everything about them screams quality, from the sturdy, fabric-encased cable to the textured titanium casing used on the buds, the 3.5mm jack plug and even the Y-junction where the cable divides in two. There's an inline remote (also titanium), as well as a choice of four sleeves (three silicone, one foam). You also get a round rubber carry case and a two-pronged flight adaptor.

The fancy ergonomic styling preferred by rivals is eschewed in favour of a simple bullet design, but they're still extremely comfortable to wear and almost impossible to shake loose. And they sound as good as they feel. They're a little on the bright side,

maybe, so they're perhaps not the best choice for serious bass fiends, but definition is crisp and clear right across the range, and they impressed on the stereo imaging front.

What's more, they took all the rough punishment we could throw at them and still came up smiling. As we said at the start, they're not cheap by any means – but we can't see anyone ever regretting buying them.

■■■■■  
atomicfloyd.com, £250

**TOUGH  
TESTS**

SNAG TEST: PASSED  
JERK TEST: PASSED  
SHOWER TEST: PASSED  
CRUNCH TEST: PASSED

RUSSELL DEEKS is a technology and music journalist, and editor of *Songwriting* magazine



CERN's CMS tracker  
was completed in  
December 2014

PHOTO: CERN





**FOCUS**  
SPECIAL REPORT

# SEARCHING FOR ANOTHER SMASH HIT

This spring, the Large Hadron Collider is switching back on.  
How will it extend our knowledge of the subatomic realm?

## CONTRIBUTORS



**JASON GOODYER**

Commissioning editor and physics  
writer at *BBC Focus*

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Prof of physics at UCL, scientist on the ATLAS  
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BEYOND THE HIGGS  
BOSON



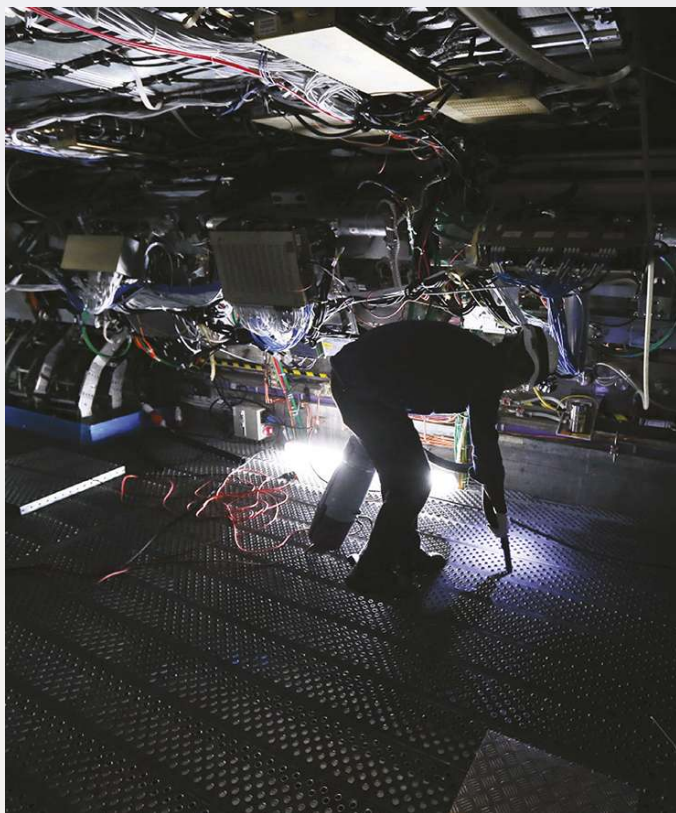


PHOTO: CERN X3

Top and above: CERN workers clean up the ATLAS particle detector ahead of the new run

Right: Technicians prepare to insert an additional subdetector on the ATLAS instrument

FOR THOSE OF us on the outside, it seems like there has been little going on at CERN since the announcement of the discovery of the Higgs boson in summer 2012. But although the Large Hadron Collider's (LHC) particle beam has been shut off since February 2013, things have been far from quiet beneath the Franco-Swiss border. Engineers and technicians have been busily repairing and upgrading the accelerator ahead of its next run.

The LHC is situated at CERN, in Geneva. It uses strong electromagnetic fields to accelerate charged particles, usually protons, around a 27km-long track at up to 99.9999991 per cent of the speed of light. Two bunches of particles are sent through the tubes in opposite directions, accelerated to the desired speed, squeezed into an area about one quarter the width of a human hair and then smashed together in dramatic collisions. It's an exercise in precision engineering that requires extreme attention to detail.

During the shutdown, 18 of the 1,232 giant (15m-long) dipole magnets used to bend the paths of the particles have been replaced. More than 10,000 electrical interconnections between the magnets have been upgraded. And the cryogenics system used to cool the superconducting magnets to temperatures of  $-270^{\circ}\text{C}$  has been given an overhaul, as have the accelerator's complex electronics.

The upshot is that the accelerator will be able to run at higher energies than ever before, up from 8TeV (tera electron volts) to 13TeV. This is key in the search for new physics. As Einstein's famous  $E=mc^2$  equation tells us, mass and energy are equivalent. When two high-energy particles smash into one another, some of their energy is converted into mass in the form of new particles. The higher the energy, the more mass there is available to create these particles.

Particles produced by the collisions are picked up by one of six detectors along the accelerator's track. The resulting data is pored over by researchers around the world, who look for signs of new science.

Read on to find out more about this incredible machine, the fundamentals of particle physics and the mysteries it could solve in the coming months.





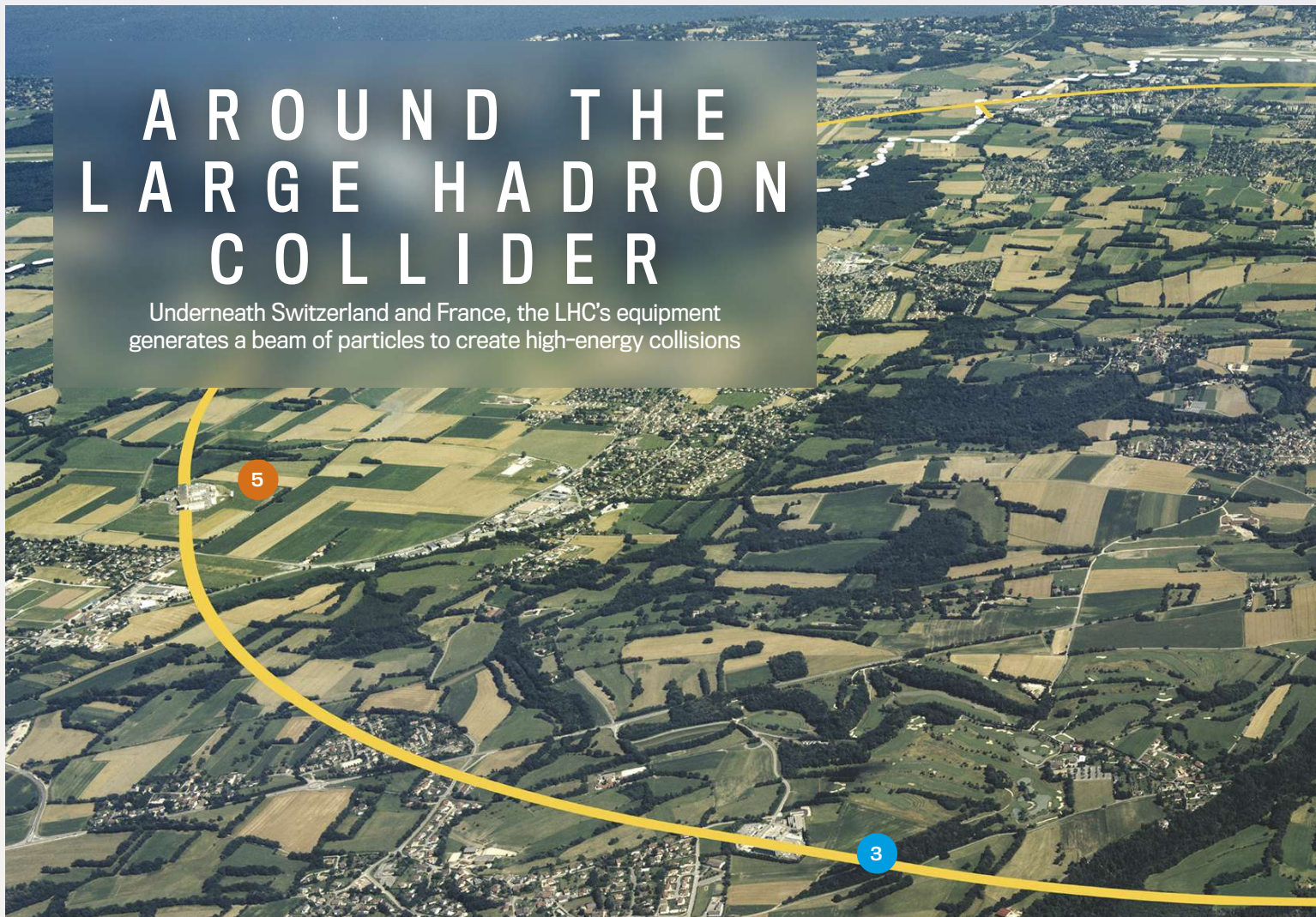
**“Although the LHC’s particle beam has been shut off since February 2013, things have been far from quiet”**





# AROUND THE LARGE HADRON COLLIDER

Underneath Switzerland and France, the LHC's equipment generates a beam of particles to create high-energy collisions



1

## LINAC LINEAR ACCELERATOR

The protons that are eventually smashed together in the LHC start out in a simple bottle of hydrogen gas. An electric field is applied to the gas to strip the hydrogen atoms of their electrons, leaving behind protons. These are injected into Linac 2, the first accelerator in the chain. From here another accelerator called the Proton Synchrotron Booster accelerates them further.



2

## PS AND SPS

The Proton Synchrotron was the world's highest energy particle accelerator when it was first switched on in 1959. Now, the 628m-long machine accelerates protons ejected from the Proton Synchrotron Booster to 25GeV. Its younger sibling, the Super Proton Synchrotron, accelerates them to 450GeV before they're injected into the LHC proper, where they will reach energies of 13TeV.



3

## LHC TUNNEL

The main tunnel housing the beam pipes is 27km in circumference and between 50m and 175m underground. For particles to pass unhindered, the pipes are kept in an ultra-high vacuum state that makes them as empty as interstellar space. The protons reach speeds of about 99.9999991 per cent of the speed of light, propelling them around the accelerator 11,100 times per second.





4

#### ATLAS DETECTOR

Beams of particles collide at ATLAS's centre, sending newly created particles in all directions. Six detecting systems, arranged in layers around the collision point, record the position and momentum of the particles so that they can be identified. ATLAS is the largest such detector ever made and measures 46x25x25m, about the length and width of an Olympic swimming pool.



5

#### CMS DETECTOR

CMS has the same general scientific goals as ATLAS but is built to a different design. It is based around a cylindrical coil of superconducting cable that can generate a magnetic field 100,000 times as strong as that of the Earth. The detector weighs as much as 10 double-decker buses and employs a workforce of more than 4,000 scientists and engineers from 41 countries.



6

#### MEYRIN CENTRE

Meyrin is home to a server farm the size of six tennis courts. It's the first point of contact between data from the accelerator and the Worldwide LHC Computing Grid. The Grid connects more than 170 computing centres in 40 countries, granting near real-time access to the 30 petabytes of data generated annually. That's enough to fill 6,300,000 DVDs.



# THE STANDARD MODEL EXPLAINED

Over many decades, physicists have created a theory that explains what's inside atoms and the forces between them

➔ **THE STANDARD MODEL** of particle physics helps scientists to classify fundamental subatomic particles and study nuclear interactions. No matter how hard we smash them together, these particles show no sign of having any internal structure. They are not made of anything else. And yet, everything else is made from them.

These fundamental particles can be classified in a number of ways, but probably the most important division is based on a property called 'spin'.

Particles that carry a whole number amount of spin (0, 1, 2 etc) are called bosons, and those that carry half-number amounts are fermions. All the 'matter' particles that make up atoms are called fermions. And particles that carry forces between the fermions are called bosons.

We can further separate fermions, the matter particles, into different types. One sub-class is the quarks. There are six varieties of quarks: up, down, strange, charm, bottom and top.

Quarks are combined into particles called hadrons. They are held there by the strong force, and that involves a huge amount of energy. This 'binding energy' is responsible for most of the mass of protons and neutrons: thus for most of the mass of atoms, and, therefore, of you. The boson carrying the strong force is known

as the 'gluon'. Quarks continually radiate and exchange gluons to such an extent that we never find a quark on its own – they are always confined inside hadrons.

The other class of particles is the leptons. The most familiar is the electron. When bound to a nucleus, electrons make up the rest of an atom. When free to move, they carry electric current and make our technology tick. The boson behind electricity, magnetism and the binding of electrons into atoms is the photon – the quantum of light.

For reasons not entirely clear, there are two copies of the electron: the muon and the tau. Just like the electron, these have a charge, but they also have more mass. This three-fold pattern mirrors that of quarks.

There is another kind of lepton, which has no electric charge – the neutrino. The only Standard Model force that neutrinos experience is the so-called 'weak nuclear force'. The quarks and other leptons also feel this force, but because it is weak, it is

usually hard to discern. Incredibly, we are continually bathed in neutrinos from the Sun (the weak force is vital in the fusion reactions that keep the Sun burning).

All fermions come with an antimatter partner: antimatter particles have the same mass but the opposite charge. And that's nearly it. Six types of quarks and antiquarks; six types of leptons and antileptons; and bosons carrying the electromagnetic force (the photon), the strong force (the gluon) and the weak force (W and Z bosons).

But there's more. Most of the mass of atoms comes from binding particles together. But the particles themselves have mass as well. Including their masses consistently in any theory presented a serious challenge. Back in the 1960s, Robert Brout, François Englert, Peter Higgs and others met this challenge in principle with the Brout-Englert-Higgs mechanism. This was then incorporated into the Standard Model over the following years. It requires the existence of a new quantum field, the Higgs field, which is present everywhere in the Universe, even in a vacuum. Interactions with this field give particles their mass, and the boson associated with the field, the Higgs boson, was discovered in 2012. This is the last piece of the Standard Model: its foundation, and its crowning glory.

**"When free to move, electrons make our technology tick"**

## PARTICLE ZOO

A quick guide to subatomic terms

### FERMIONS

Particles with a half-number of spin. These 'matter particles' make up atoms

### QUARKS

A sub-class of fermion. There are six types (up, down, charm, strange, bottom, top) along with antiquarks

### BOSONS

Particles with a whole number of spin. These carry forces between fermions

### PHOTON

A type of boson that carries the electromagnetic field

### GLUON

A type of boson

that carries the strong force

### W AND Z BOSONS

These carry the weak force

### HIGGS BOSON

This proves the existence of the Higgs field, which gives all particles their mass

### LEPTON

Another type of particle. The best known is an electron. Each has a corresponding antilepton

### MUON AND TAU

These leptons are copies of the electron. They have a charge, but a lot more mass than the electron

### NEUTRINO

A type of lepton. There are three varieties, which all have no electric charge

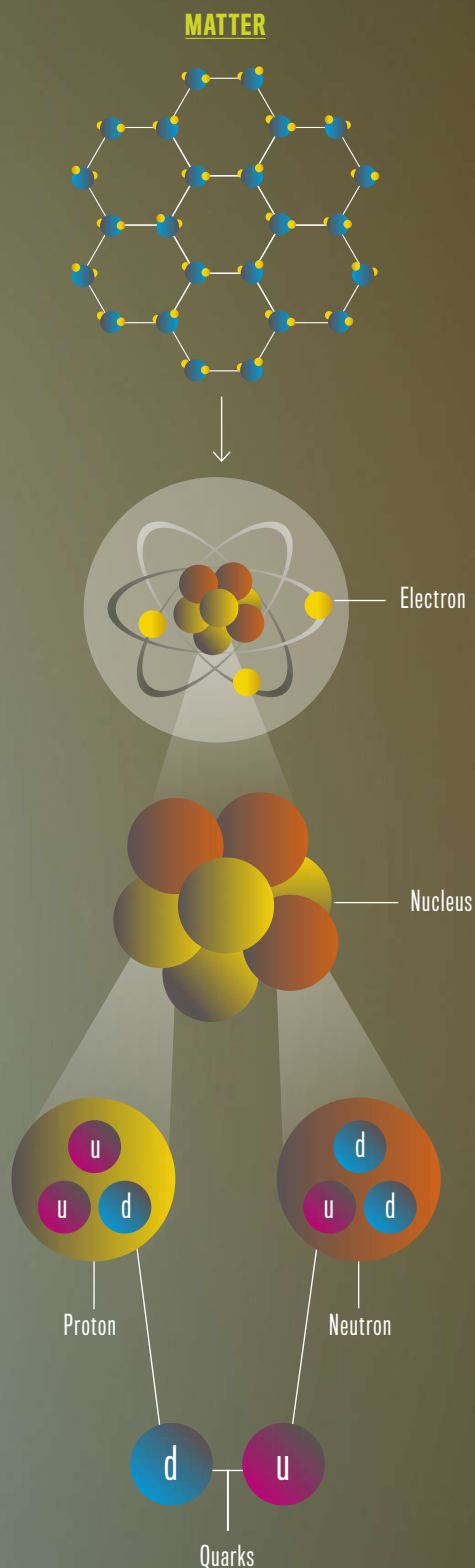
### SPIN

This is the angular momentum by which all particles are classified



## FERMIONS

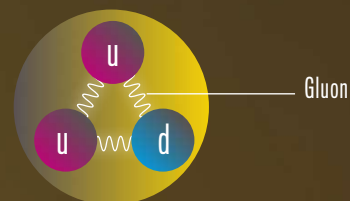
Particles that make up atoms



## BOSONS

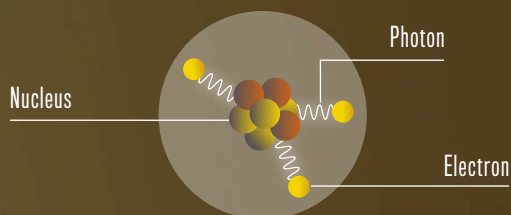
Particles that carry forces between fermions

### STRONG FORCE



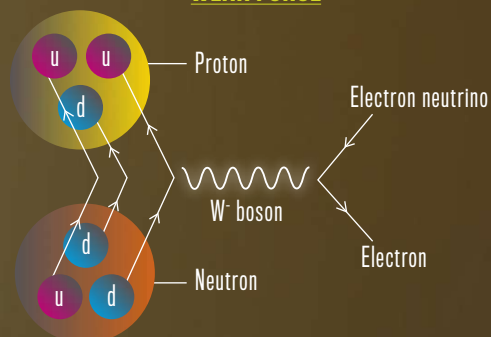
Gluons bind quarks to form hadrons, and hadrons to form atoms

### ELECTROMAGNETIC FORCE



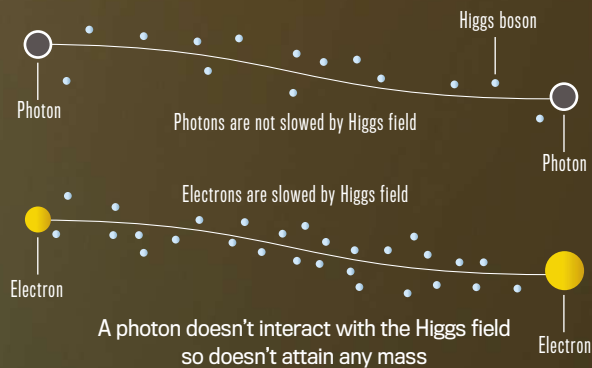
Photons bind electrons to atoms, and atoms to atoms to form molecules

### WEAK FORCE



The W boson is involved in natural radioactivity such as beta decay, shown here

### HIGGS FIELD





# BEYOND THE HIGGS BOSON

After discovering the long-sought particle, what are scientists hoping to find this time around?

THE HIGGS BOSON was discovered using collision data recorded in the first run of the Large Hadron Collider, from late 2009 until the end of 2012. In spring 2015, after maintenance of the magnets, detectors and other infrastructure, collisions will start again at higher energy. What might we learn from the LHC's second run?

Experimentally, there are two main reasons why the new LHC data can take us further. The first is down to the quantum-mechanical, and hence probabilistic, nature of the processes we study. You might think that when two protons collide at a particular energy and angle, the results would be predictable, and always the same. In that case, if you have measured something once, why measure it again?

In fact, we can only predict the probabilities. A pair of colliding protons has many options open as to what it might produce. The Standard Model tells us how often to expect these various possibilities, on average, but it can't tell us how an individual collision will develop. This means that if we want to investigate rare possibilities, we need more collisions. It is as though we are trying to test whether a pair of dice is fair. The more times we roll the dice, the more sure we can be – and the more likely we are to spot any unexpected biases, which might be clues to missing elements in our knowledge.

---

## MORE HIGGS BOSONS

Precise measurements will reveal how the Higgs field works

AN ESPECIALLY IMPORTANT and rare 'side of the dice' is the newly discovered Higgs boson. Once produced in a collision, the boson decays almost instantly into other particles. And again, it has several options open to it, and the rates of the different decays are also subject to quantum statistics. Since the Higgs field gives particles mass, the rates that certain particles are produced in Higgs decays are predicted to depend strongly on their mass. Making precise measurements of this is vital to our understanding of how the mass mechanism really operates.

So far, we have clear observations of the Higgs boson decaying into photons and to W and Z bosons. Among the

fermions, only the tau lepton decays have been seen clearly, with some evidence of decays to bottom quarks. None of these measurements are very precise, and we would like to know more.

More data will also allow us to examine other properties of the Higgs boson more precisely – for example, how quickly does it decay? And is it even a fundamental particle, or might it contain the first clues to another layer of substructure? We would also like to see the Higgs interacting with itself, since this is how it is supposed to give itself mass, though that is a very difficult measurement.

There might also be heavier Higgs bosons out there just waiting to be found!



# S U P E R S Y M M E T R Y

This could be the last chance for the LHC to find the predicted partners of the known particles

THE SECOND RUN will have more energy and that can help us learn more. We can potentially make new, more massive particles. It will give us improved resolution, allowing us to study the particles and forces more closely.

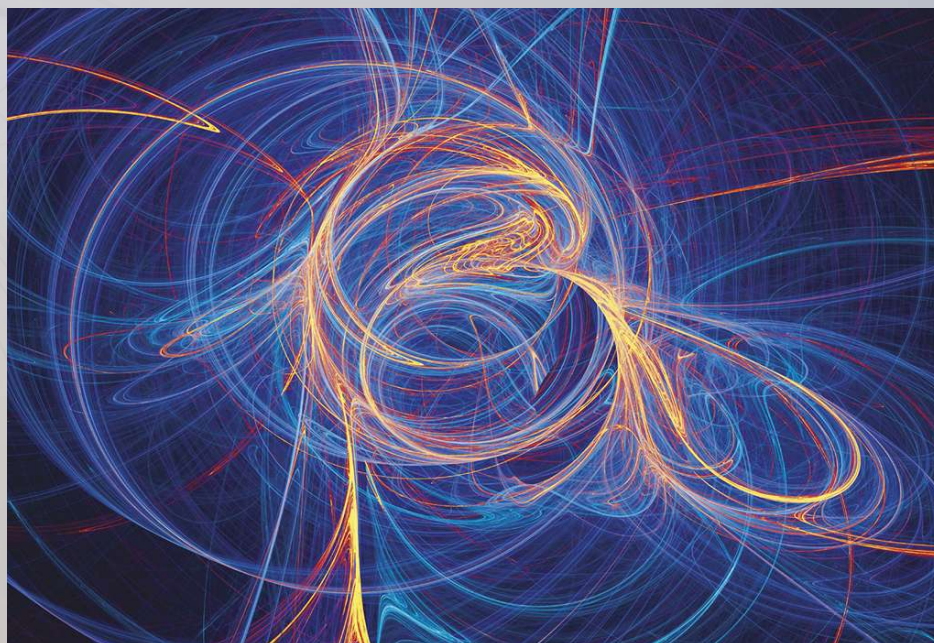
You might wonder why, since the Standard Model seems to be complete, we would even think there might be more particles out there. In fact, there are several excellent reasons to think that the Standard Model cannot be the final word.

For one thing, gravity does not fit. It is not included in the Standard Model or in any quantum theory. It is described by General Relativity, sitting somewhat awkwardly off to one side. Luckily, the effects of gravity on fundamental particles are weak enough that it can largely be ignored, for now at least. This means the Standard Model can hardly pretend to be a theory of everything.

There are also several apparently arbitrary features in the Standard Model. For example, as mentioned earlier, why are all the force-carriers bosons, and the rest fermions? By including the Standard Model into a larger theory, such arbitrary features can either be removed, or made an inevitable part of the larger structure.

One popular extension to the Standard Model is known as 'supersymmetry'. Supersymmetry removes the arbitrariness between fermions and bosons, by introducing a fermion partner for every boson and vice-versa. They allow them to transform seamlessly into one another at high energies. The extra symmetry in these theories helps explain why the mass of the Higgs, W and Z bosons is low enough that we can actually study them. Without such extra symmetry, many theorists think the most natural value for these masses would tend to be very high – up to a billion billion times higher, near what is called the 'Planck mass'. This is where gravity becomes so strong that it would have an effect in this tiny realm. It seems unlikely that the LHC will be able to help much with bringing gravity and the Standard Model together. However, the discovery of supersymmetric partners of the Higgs, or other particles, would be hugely exciting.

Supersymmetry predicts many new particles – partners for all the existing ones, plus three extra Higgs bosons. But the problem is that none of these have shown up yet. The second run at the LHC may be their last chance!



Left: Supersymmetry allows particles to transform into one another at high energies



# CLUES TO ANTIMATTER

Rare particle decays could explain why there's more matter than antimatter

THERE ARE FOUR big particle detectors at the LHC. Two of them, ATLAS and CMS, discovered the Higgs boson and are general purpose detectors. The other two detectors are more specialised.

ALICE is optimised for those periods (usually a few weeks a year) when the LHC collides lead nuclei rather than protons. ALICE, ATLAS and CMS can all use such collisions to study exotic forms of matter, but ALICE has some unique advantages.

The final detector is LHCb, where the 'b' stands for the bottom quark. Many of these massive quarks are produced in the proton-proton collisions at the LHC. LHCb is specifically designed to detect as many of them as possible, and measure the different ways in which they decay to lighter particles.

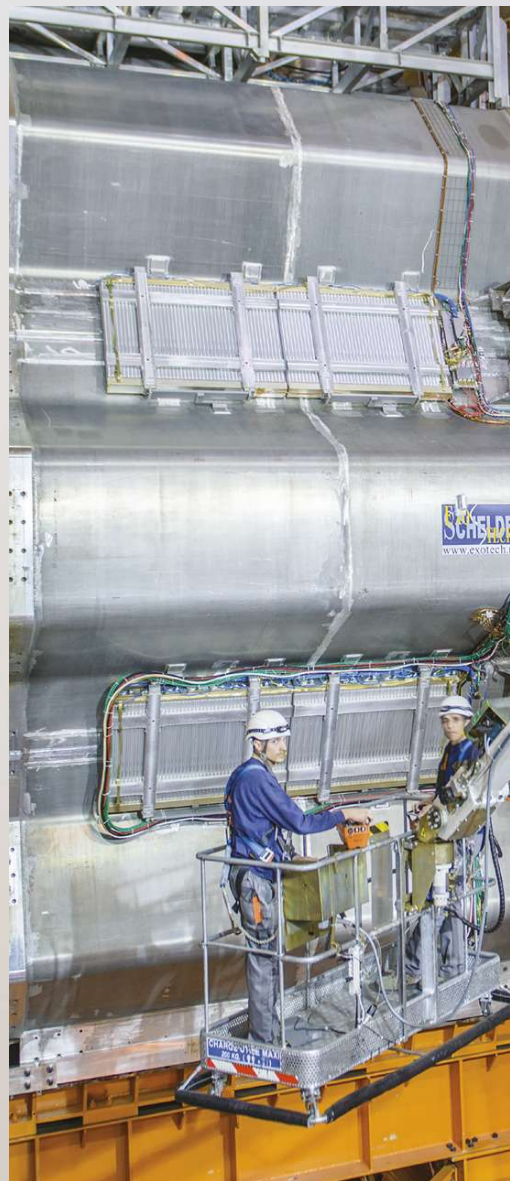
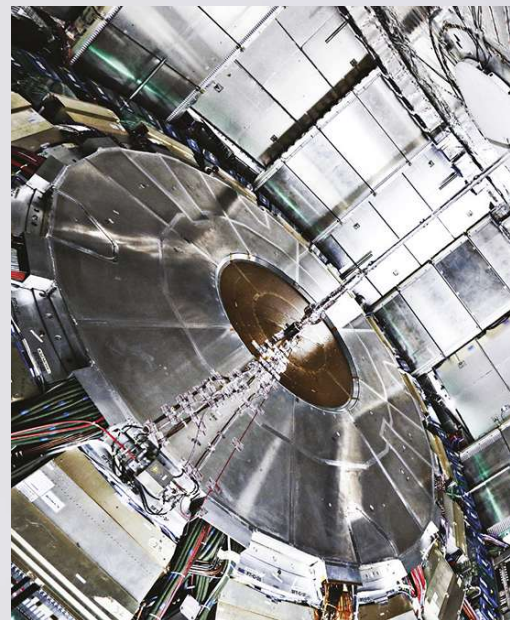
Rare decays of particles like this are interesting for a number of reasons. For one thing, they can occur via tiny 'quantum loops', involving particles that are much too heavy to be produced directly. Measurements of such decays have already contributed to ruling out many possible new theories, including variants of supersymmetry. With more

data in the second run, more theories will be on the chopping block.

Decays of bottom quarks are especially interesting for reasons connected with the 'missing antimatter' in the Universe. In the Standard Model, particles and antiparticles are almost always produced in equal numbers – but the Big Bang seems to have left us with lots of matter and no antimatter. How? Where did all the antimatter go?

B-quarks are the heaviest version of the down quark (the strange quark lies between them in mass). Nobody knows why there are three copies of particles like this. But we do know that three is the minimum number for which it is possible to introduce some matter-antimatter asymmetry (known as CP-violation), into the theory. Measuring the b-quark decays is a very direct way to probe CP-violation, and LHCb has measured the effect.

Unfortunately, the measured asymmetries do not seem to be big enough to account for the vast difference in abundance of matter and antimatter that we see around us. However, there is still more to learn here, and extra data from the second run will help increase our understanding.



Two particles annihilate forming a Z particle, which decays into a b-quark and antiquark

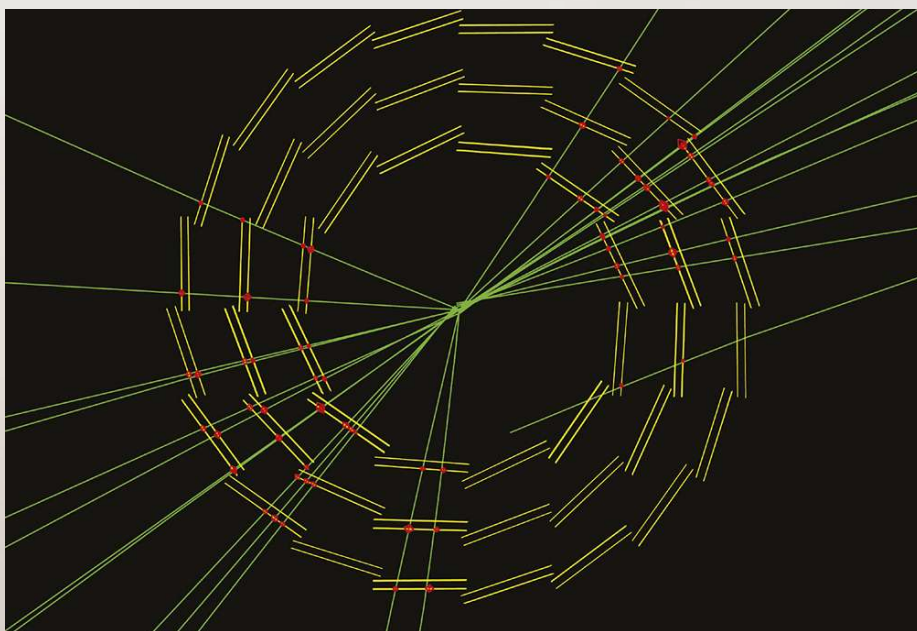
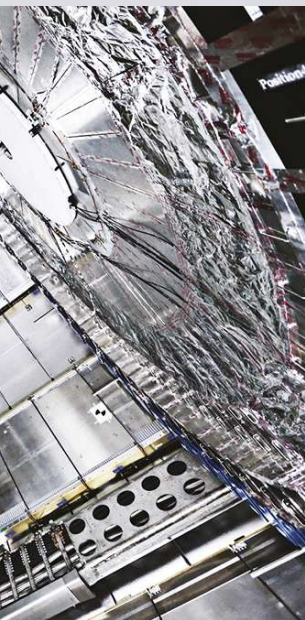
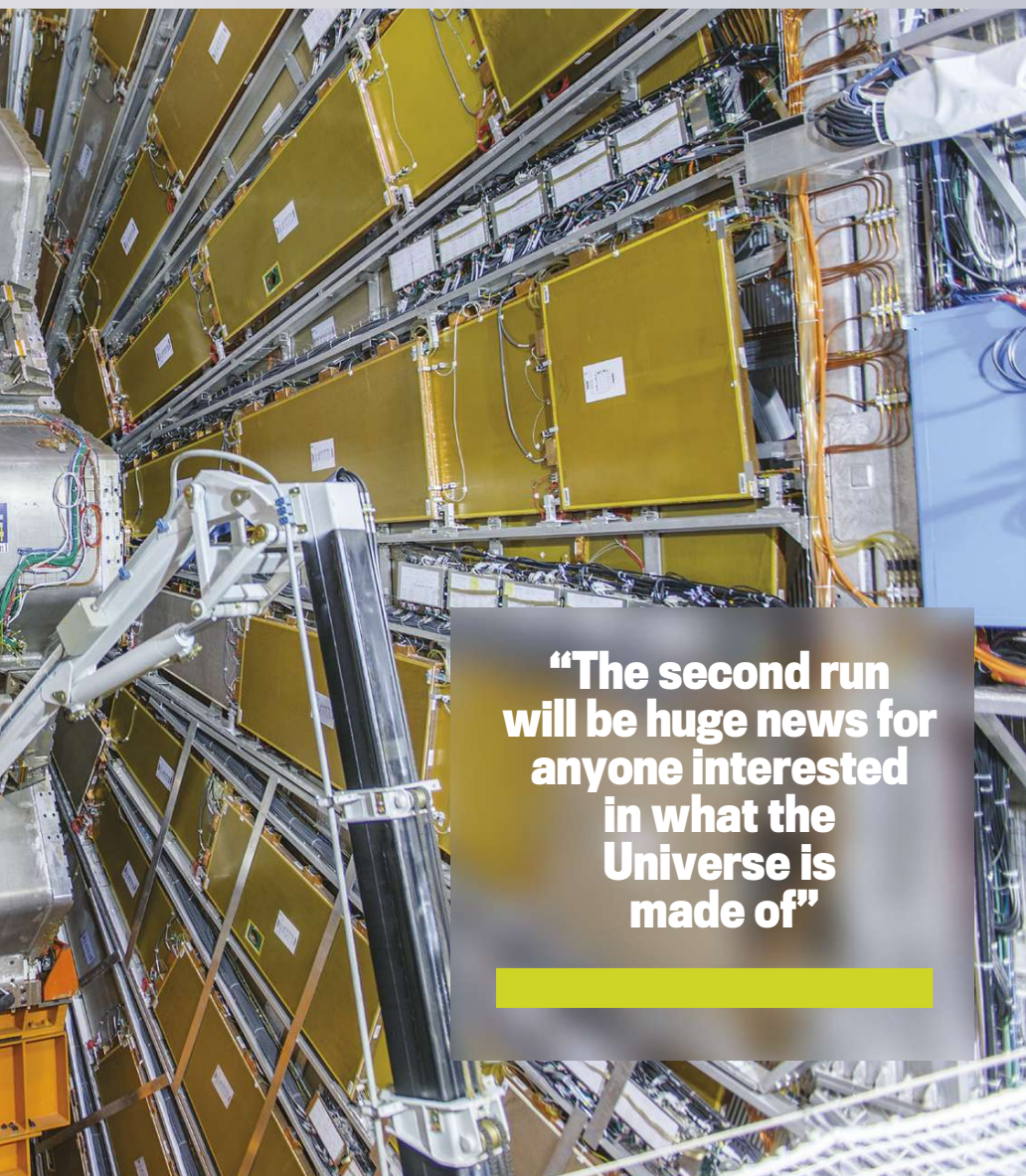
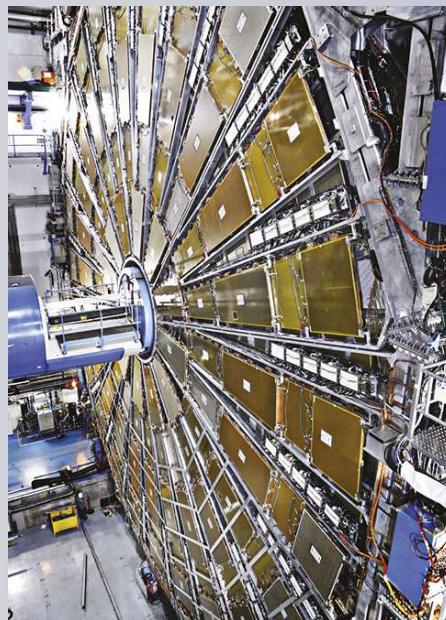


PHOTO: CERN X3, SCIENCE PHOTO LIBRARY





Along with the CMS detector, the ATLAS detector (pictured) found the Higgs boson



**“The second run will be huge news for anyone interested in what the Universe is made of”**

## DARK MATTER

There's stuff out there we can't see, and the LHC might spot it

ANOTHER PROBLEM NOT solved within the Standard Model is the observational evidence that the Universe is filled with more matter than we can see. This is known as dark matter and does not seem to consist of any of the known particles. Far from ‘everything else’ being made of the quarks and leptons, astrophysical observations and cosmological models indicate that about 84 per cent of matter is something not contained in the Standard Model.

Supersymmetry suggests that dark matter could be a supersymmetric partner particle. If so, then there is a fair chance that we might actually be able to produce, and indirectly detect, pairs of dark matter particles in the new collisions. Several of the possible extensions of the Standard Model provide candidates for dark matter particles that might be produced at the LHC. In many of these theories, even if dark matter doesn't interact much with other particles, it still gets its mass from the Higgs field. Studying the Higgs boson (or bosons!) carefully is vital.

There are other experiments going on around the world that can tackle some of these issues too. Sensitive underground detectors are hunting for the glancing impacts of the dark matter particles that ought to be drifting past us all the time. High-energy cosmic ray experiments, other astrophysical observations, and precision measurements also have things to tell us. Perhaps most importantly, neutrino experiments are running or planned. And these could tell us whether the tiny mass of the neutrino comes via the mechanism proposed by Brout, Englert and Higgs, or by a more exotic route that involves it being its own antiparticle. Neutrino experiments will contribute to, or constrain, the possibilities for physics beyond the Standard Model.

The LHC is not the only exciting thing going on in particle physics over the next few years. But the second run will be huge news for anyone interested in what the Universe is made of. ■



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-  **LISTEN**
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-  **READ**

## PICK OF THE MONTH



## Stargazing Live

Join Prof Brian Cox, Dara O'Briain and Liz Bonnin at Jodrell Bank for this month's solar eclipse

➔ "ZEUS, THE FATHER of the Olympic Gods, turned midday into night, hiding the light of the dazzling Sun, and sore fear came upon men." So wrote Greek poet Archilochus, one of the first to record the experience of a total solar eclipse. Back in 648 BC, it was seen as an omen from the gods. Today, we know that these awe-inspiring events happen when the Moon passes between the Sun and the Earth, obscuring the Sun's disc and blocking its light.

This year promises to be an exciting one for eclipse chasers. A total solar eclipse will be visible from parts of Europe and the Arctic on 20 March – the last one to be visible in Europe until 2026. To celebrate, *Stargazing Live* is returning for its fifth season, timed to coincide with the astronomy event of the decade.

On the morning of the eclipse, Liz Bonnin will report live from the Faroe Islands – one of the few landmasses to lie in the path of the total eclipse (the other being the Svalbard archipelago in the Arctic Ocean). Liz will take to the skies in the *Stargazing Live* plane to capture breathtaking views of the total eclipse as it happens. There'll also be plenty of tips on how to enjoy the spectacle yourself,

with a partial eclipse being visible across the whole of the UK. Pinhole projectors at the ready!

But eclipses aren't the only event on this year's menu. As usual, Prof Brian Cox and Dara O'Briain will host proceedings from Jodrell Bank Observatory, and they'll be joined by Liz Bonnin, Dr Lucie Green and Dallas Campbell for three nights of space-filled adventures. Among the highlights: Apollo Lunar Module pilot Rusty Schweickart gives Brian a lesson in how to land on the Moon, Lucie reveals what's so special about the North Star and Dallas finds out what goes on inside ESA's spacecraft testing centre in the Netherlands.

There'll also be an opportunity for viewers to get involved in some citizen science, with the chance to discover their very own supernova. So there's no excuse not to get involved in some serious stargazing this March.

**JAMES LLOYD**



Watch *Stargazing Live* on BBC Two, 18-20 March and the eclipse special on BBC One, 20 March

## DON'T MISS!



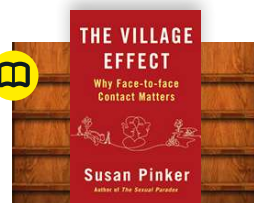
## Hubble's Cosmic Journey

Take a look back over the space telescope's troubled past. **p100**



## Great Thinkers: Daniel Dennett

Hear the American philosopher and cognitive scientist deliver his thoughts on the possibility of a unified theory of information. **p103**



## The Village Effect

Is our growing connection to the digital world making us disconnect from each other? **p104**





# WATCH

TV, DVD, BLU-RAY & ONLINE  
WITH TIMANDRA HARKNESS

8 MARCH

## Malaysian 370: What Happened?

National Geographic, 8pm



ON 8 MARCH 2014, a routine flight from Kuala Lumpur to Beijing turned into an aviation tragedy when the plane vanished with all on board. One year later, this programme revisits the mystery. It examines competing theories about the fate of flight 370, and how investigators continue to pursue the truth in the face of vast distances and the passage of time.

FROM 10 MARCH

## Alien Files: Unsealed

H2, 9pm



THIS SERIES USES recently declassified files to investigate historic sightings of UFOs. Some will believe there are mysteries that somebody wanted to keep under wraps. Others may think that UFOs were convenient smokescreens when governments had something to cover up. Either way, there's plenty here to please a UFO fan.

FROM 13 MARCH

## Richard E Grant's 7 Deadly Sins

Discovery, 9pm



THE SEVEN DEADLY sins are familiar from the Bible. But in this seven-part series, actor Richard E Grant (pictured) takes a scientific view by finding counterparts to human vices in the animal kingdom. Will he meet an envious eel or a slothful, er, sloth? If nothing else, "it evolved as a survival mechanism" is a great excuse when you're caught sinning.

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze



Astronauts working on the Hubble Space Telescope

EDITOR'S CHOICE

18 APRIL

## Hubble's Cosmic Journey

National Geographic, 8pm

THE HUBBLE SPACE Telescope is one of NASA's iconic achievements. It's an eye on the heavens that, by escaping the Earth's atmosphere, sees farther in space and time than we've ever seen before. Images it has captured of deep space and distant objects adorn millions of walls and computer screens, and fill the dreams of adults and children.

But at one point, the ambitious engineering mission looked like NASA's biggest failure. It seemed an expensive mistake that revealed flaws in the agency's work, going much deeper than the optical failings of Hubble's vast reflector.

The story of the dedicated scientists, engineers and astronauts who spent 20 years of their lives conceiving and realising the vision is bound up with the history of the space shuttle programme, rocked by the Challenger tragedy.

In this programme, shuttle pilot Charlie Bolden, now head of NASA, recalls the mission to deploy Hubble. It was threatened by unforeseen technical mishaps, which almost scuppered the \$3bn mission before it had even begun.

Relief when the space telescope was finally deployed turned again to heartbreak when the first images were sent back to Earth. Optical faults of a millionth of an inch, that should have been detected before launch, meant distortions on a scale that rendered them useless to scientists.

Director Chris Riley follows his award-winning film *In The Shadow Of The Moon* with this tense account of how NASA overcame so many obstacles. You'll never take Hubble's gorgeous photographs of space for granted again.



**20 MARCH**

## One Way Astronaut

Eden, 8pm



WOULD YOU LIKE to go into space, to walk on another world? Yes? What if the price was never coming home? Tens of thousands of people said yes, and applied for the Mars One initiative. Mars One founder Bas Lansdorp plans to raise \$6bn by treating a Mars mission as a reality TV series. Find out more in this one-off documentary about the project.

**24 MARCH**

## Insect Dissection

Eden, 9pm



BEFORE YOU SQUASH that insect, admire the perfection of its anatomy... and hand it over to be dissected. Entomologists Brendan Dunphy (pictured) and James Logan take apart an insect layer by layer, showing in close-up how everything works. This programme reveals nature at its most impressive, and science at its most fiddly.

**30 MARCH**

## Hangar 1: The UFO Files

H2, 10pm



→ YES, THERE'S MORE on UFOs from H2 this month. Since 1969, MUFON – the Mutual UFO Network – has investigated UFO sightings across 42 countries around the world. Over 30,000 files have now been assembled in an abandoned hangar in Ohio. By pulling together common themes from several files, this series tells a different story in each episode. Rogue technology, presidential cover-ups and weird patterns emerge from the sightings, images and physical evidence in Hangar 1.

## DVD & BLU-RAY



### David Attenborough's Conquest Of The Skies

Sky, £14

DAVID ATTENBOROUGH GOES back 300 million years to tell the story of how animals evolved flight. It's not just birds that took to the skies.



### Silicon Valley

HBO, £25.52

THIS COMEDY SERIES is set in a high-tech world where everyone dreams of being the next Steve Jobs. It's written by Mike Judge, a former Silicon Valley engineer turned comedy writer.

## ONLINE

**BBC**

### Auxetic Materials Used In Protective Wear

<http://bbc.in/1zSjmbU>


Fran Scott gets serious about structures

FRAN SCOTT FINDS out how a material inspired by nature gets stronger and fatter when stretched. She then shows you how to make a structure to illustrate these properties.

**BBC**

### Creating Light

<http://bbc.in/1talLsT>


Mark Miodownik makes bright, smelly light

IN THIS CLIP from the BBC's *Everyday Miracles* series, Prof Mark Miodownik shows how to create light from electricity in a way that's "not at all practical for the home".

**BBC**

### Story Of Now

<http://bbc.in/1wDHNom>


PSYCHOLOGIST, AUTHOR and broadcaster Claudia Hammond takes a closer look at time perception and discusses whether it's just an illusion in this interactive video from the BBC Connected studio.





## LISTEN

### BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

7-8 MARCH

### Shaking The Foundations: The Forum

BBC World Service, various times

BRIDGET KENDALL WRANGLES a panel including stand-up mathematician Matt Parker, biologist Armand Leroi, writer Will Self, and international politics expert Leslie Vinjamuri. Wish her luck as they collide over philosophy, creativity and at least two kinds of infinity.

FROM 17 MARCH

### Restarting The Antibiotic Pipeline

BBC Radio 4, 8.15pm

THE LAST TRULY new antibiotic arrived in the 1980s. Since then, research and development on the next weapon in the war on bugs has stalled. In this two-part documentary Roland Pease finds out why this is the



Where are all the new antibiotics?

case, and meets those who are trying to restart the quest for new lifesaving drugs.

28-29 MARCH

### Fridgeconomics

BBC World Service, various times

IMAGINE YOUR LIFE without a fridge. How would it change how you shop, cook and eat? Elizabeth Ohene goes into kitchens around the world to find out why it's such an aspiration in developing countries, and how the advance of the fridge could affect economies, education and the environment.



Fridges do more than keep your beer cold

7 APRIL

### 3D Bio Printing

BBC Radio 4, 11am

BY LAYERING SUITABLE materials, 3D printing can make almost anything. In 2009, Harvard researchers printed living cells, opening the door to manufactured body parts for medical use. Could 3D printing bring back extinct species?

PODCAST

### A History Of Britain In Numbers

<http://bbc.in/1dx1eNv>



THIS IS THE second season of the series that uses numbers to tell the story of our past. Andrew Dilnot, chair of the UK Statistics Authority, starts with the relationship between knowledge and power, statistics and the state, and ends up in a muddy field.



## TOUCH

### SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

### Moon Globe HD

iOS 7.0 or later, iPad/iPhone/iPod Touch, Midnight Martian, 79p



Apollo 11 making the final descent to the Sea of Tranquility.

ONLY 12 PEOPLE have ever walked on the Moon. You're unlikely to tread in Neil Armstrong's footsteps, but *Moon Globe HD* offers the next best thing. Using high-res satellite imagery, this detailed 3D globe can be viewed in a number of ways. It reveals topographic features, plus all the craft that have ever landed. Simply tap a label to bring up an information panel with links to online resources. You can even turn on Anaglyph 3D mode to don your specs and pretend you're in

### Particle Adventure

iOS 6.0 or later, iPad/iPhone/iPod Touch, Android 2.1 or later, Berkeley Lab, free

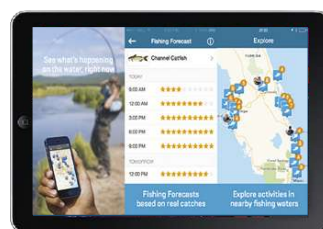


who wants to be able to tell a quark from a neutrino.

OUR BEAUTIFUL PLANET is abundant with life and variety, but physicists know that all matter is made up of a few fundamental building blocks. Explore the mysterious and invisible world of subatomic particles in *Particle Adventure*. This free app takes you on an interactive tour, asking and attempting to answer some of the greatest questions ever posed by humanity. The app itself is not that glossy to look at, but the information is well written and extensive – it's perfect for anyone

### FishBrain

iOS 7.0 or later, iPad/iPhone/iPod Touch, Android 4.0.3 or later, FishBrain, free



waters from around the world. It will not only use scientific data to help you prepare for a successful fishing trip, but will also allow keen anglers to share information and photos of the best locations to land that dream catch.

BEING A GOOD angler takes a bit of knowhow. Which bait or lure works best? What are the ideal atmospheric conditions for a good catch? *FishBrain* can help, by hooking into meteorological data and a catalogue of over 50,000 lures and 1.7 million fishing

KATE RUSSELL is a technology journalist and BBC *Click* presenter





# VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

14-15 MARCH

## FutureFest

Vinopolis, London, £80 (weekend ticket), [futurefest.org](http://futurefest.org)

THIS TWO-DAY festival aims to excite and challenge your perceptions of the future. Edward Snowden is a confirmed speaker.



UNTIL 15 MARCH

## Rights Of Nature

Nottingham Contemporary, Nottingham, [bit.ly/1AfBkGt](http://bit.ly/1AfBkGt)

THROUGH PHOTOS, DRAWINGS and other media, artists analyse our fraught relationship with the natural world in the face of global warming, environmental destruction and mass extinction.



19 MARCH

## Stories In The Stars

Royal Observatory, London, 7pm-8.30pm, £7, [rmg.co.uk](http://rmg.co.uk)

MOVE OVER *CRACKANORY* - this is how to do storytime with a difference! Relax under the stars in the planetarium as author Susanna Hislop reads from her book *Stories In The Stars*.

23 MARCH

## Dinosaurs, Epigenetics And The Higgs

Royal Institution, London, 2pm-5pm, £20, [rigb.org](http://rigb.org)

PALAEONTOLOGIST DAVID HONE explores dinosaur behaviour, physicist Jon Butterworth reveals how the Higgs boson was discovered and biologist Nessa Carey explains epigenetics.



26 MARCH

## The Green Economy

Watershed, Bristol, 7.30pm-9pm, free, [ideasfestival.co.uk](http://ideasfestival.co.uk)

WATCH THIS DISCUSSION on how to develop the economy while cutting environmental risks and ensuring sustainable development.

27 MARCH

## Telescopes Of The Future

Royal Institution, London, 7.50pm-9.15pm, £17, [rigb.org](http://rigb.org)

THIS TALK REVEALS how observatories in space and on the ground will cast new light on some of the biggest mysteries.



Daniel Dennett's talk is sure to inspire

**EDITOR'S CHOICE**

18 MARCH

## Great Thinkers: Daniel Dennett

Condé Nast College of Fashion & Design, London, 12.45pm-1.45pm, £25, [www.howtoacademy.com](http://www.howtoacademy.com)



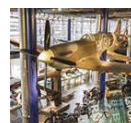
THE EVER CONTROVERSIAL Daniel Dennett is a key philosopher of our time with his thought-provoking arguments about consciousness, free will and human evolution. In this lunchtime talk, he explains how common threads in evolution, learning and engineering account for a unified theory of information in the Internet Age.

FROM 28 MARCH

## The Innovation Race

MOSI, Manchester, until March 2016, free, [mosi.org.uk](http://mosi.org.uk)

DISCOVER HOW MANCUNIAN makers helped Britain win WWI. Hear the stories of scientists and engineers, get hands-on with gadgets and view never-before-seen letters.



FROM 28 MARCH

## Spitfire Gallery

Thinktank, Birmingham, [bit.ly/1ux3UNQ](http://bit.ly/1ux3UNQ)

BIRMINGHAM MADE OVER half the Spitfires during WWII. Learn about the science of flying, then see a real Spitfire and a Hurricane.

2 APRIL

## The Science Of Game Of Thrones

Life Science Centre, Newcastle, 6pm-7.30pm, £4, [life.org.uk](http://life.org.uk)

ARE YOU A fan of *Game Of Thrones*? Don't miss this talk by Radio 4's Helen Keen as she delves into the science behind the saga.

14 APRIL

## The Unknown Universe

Royal Astronomical Society, London, 1pm and 6pm, [www.ras.org.uk](http://www.ras.org.uk)

FIND OUT WHY we can't fully prove the Big Bang theory at this talk by astro-guru and award-winning author Dr Stuart Clark.





# READ

THE LATEST SCIENCE BOOKS REVIEWED

**H** Hardback **P** Paperback

## The Village Effect

### Why Face-To-Face Contact Matters

Susan Pinker

Atlantic Books **P** £14.99

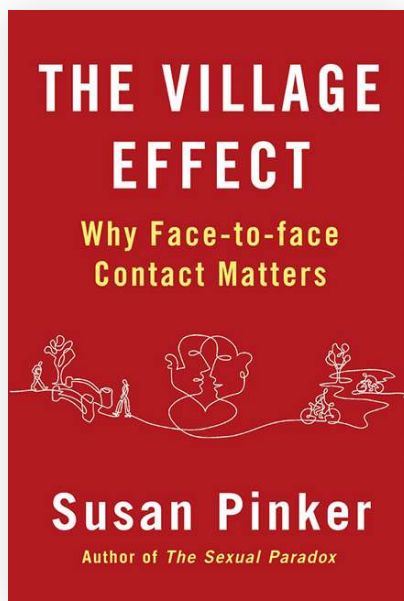
ON TWITTER, I have nearly 13,000 followers. Yet in the 'real world', how many people could I truly turn to? A handful, at most. I might have been a case study in Susan Pinker's new book. She describes how we're digitally interconnected on an unprecedented scale, and yet we're more lonely and isolated than ever.

This is bad for our health. Pinker cites one 12-year study of thousands of nurses who'd been diagnosed with cancer. Those who felt socially isolated were 66 per cent more likely to die during the investigation. Or consider a meta-analysis of 148 studies collectively involving over 309,000 people. It found that those integrated into their communities had half the risk of dying. Indeed, epidemiology finds real-world contact to be vital for long life.

Pinker repeatedly says that digital contact doesn't afford the same psychological benefits as in-the-flesh relationships. She takes us to a Sardinian hilltop village that boasts an abundance of centenarians – a place where everyone knows each other and multiple family generations live under one roof. Physical proximity, touch, trust, gossip and a powerful sense of belonging: these are the villagers' secrets to long life and happiness, explains Pinker.

**"I think we know intuitively the value of face-to-face contact. But the digital world is here to stay"**

PHOTO: SUSIE LOWE



We also hear about the limitations of online dating (their algorithms don't work, says Pinker), the financial scams orchestrated by trusted friends (the 'dark side' of face-to-face psychology), and the misguided programmes that have delivered laptops to developing nations, where investment in better teachers would have been more effective.

I winced a few times at Pinker's treatment of neuroscience, especially her simplistic caricature of the 'cuddle hormone' oxytocin and mirror neurones. More troubling is the book's bias. Pinker omits or dismisses important findings, such as a 2013 study that found moderate internet use by youths was correlated with more participation in sports and clubs; or another that found feelings of Facebook connectedness were associated with 'lower depression and anxiety and greater satisfaction with life'.

I think we know intuitively the value of face-to-face contact. But the digital world is here to stay. For me, then, what's important is how to leverage our new digital tools to foster and cultivate real, meaningful relationships. On this point, I wish Pinker had more to say.



**CHRISTIAN JARRETT** is a psychology writer. His latest book is *Great Myths Of The Brain*

## MEET THE AUTHOR



**Susan Pinker**

### How does communicating face-to-face benefit us compared to online?

Communicating in person is not only essential for forming lasting bonds, but it also has an impact on the brain that hasn't so far been detected with electronic communication. In 2010, neuroscientist Elizabeth Redcay compared the brain activity of people who were interacting in person versus those who were watching a video of a very similar interaction. When the social partner was in the room, there was much greater blood flow to brain areas associated with social cognition, perception, attention and reward.

### Lots of people find it easier to make friends online – can't social media be a useful tool in this case?

Within limits. For people who find it very difficult to communicate face-to-face, such as those on the autistic spectrum, interpersonal contact is a skill they have to learn and practise. Friends they make online don't necessarily translate into offline friendships. You can have a friend on Facebook and feel closer to them by sharing information, but you may not be getting the benefits of an intimate bond.

### What would be your three tips for living in this digital age?

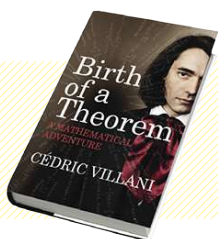
First, try to build a village effect into your daily life. If you're moving to a new area, look for one where people chat to each other in public spaces. Second, if you're a parent, limit your children's screen time – their brains are built for interacting face-to-face. Third, get up and talk to your colleagues. The teams who communicate in person are more productive, cohesive and loyal than those who mainly communicate through digital media.



### MORE ON THE PODCAST

Listen to the full interview with Susan Pinker at [sciencefocus.com/podcasts](http://sciencefocus.com/podcasts)





## Birth Of A Theorem

A Mathematical Adventure

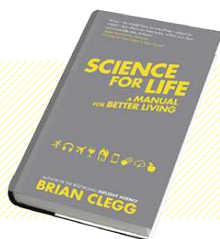
Cédric Villani

Bodley Head, **H** £18.99

IN 2010 CÉDRIC Villani won the Fields Medal, the mathematical equivalent of a Nobel Prize. *Birth Of A Theorem* describes how his prize-winning research took shape over the preceding two years. This is no popular science book – even readers with maths degrees will struggle with Villani's terminology and equations. Rather, it is an undiluted account of life as a mathematician. The main story focuses on Villani's pursuit of his elusive 'Landau damping' proof. He navigates setbacks and self-doubt, recounting moments of inspiration. The pages are scattered with excerpts, quotes and poems. It reads almost like a diary and makes for a fascinating – yet frustrating – book. There are some wonderful parts, such as when he compares algorithms that exploit randomness to the meandering in his own career path. But these are often lost among reproductions of emails and mathematical derivations. By telling the story of his quest, Villani reveals a rarely glimpsed world and shows the dedication required to reach the very top. However, by including so much unfiltered detail, the complexity of his journey will leave many readers behind.



ADAM KUCHARSKI has a doctorate degree in applied mathematics from Cambridge



## Science For Life

A Manual For Better Living

Brian Clegg

Icon Books **H** £16.99

IS COFFEE GOOD for you, or bad? If you read the newspapers you can be forgiven for not having the foggiest idea. Every day, we're bombarded with stories contradicting what we read the previous week – about everything from climate change and brain training games, to the benefits (or not) of drinking red wine.

Brian Clegg has produced the ultimate antidote. In *Science For Life*, he has researched the evidence for and against these claims – and over 200 more. For example, did you know that saturated fat is no worse for you than unsaturated? Or that there's no evidence whatsoever for the Mozart effect? Or that a UK-grown tomato comes at three times the environmental cost of one produced in Spain, thanks to the need for heating in our chilly climate?

*Science For Life* is divided into various headings, with a 'Fun' section that offers a scientific slant on topics such as why buses arrive in clusters and how to get served quickest in a queue (this is a field Clegg helped to develop while working at British Airways). This handy, well-written guide is a triumph of reason over press release reporting.



PAUL PARSONS is a science writer and a statistical analyst at Botsphere



## How To Fly A Horse

The Secret History Of Creation, Invention, And Discovery

Kevin Ashton

William Heinemann **H** £20

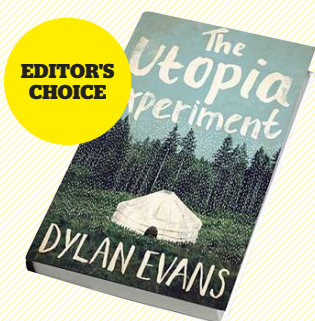
CREATIVITY IS PROBABLY the most important thing that distinguishes us from other animals. It is something that many of us dream of harnessing, but attribute it to other people. Kevin Ashton's engagingly titled new book argues against letting ourselves be intimidated. As a tech entrepreneur, co-founder of an MIT laboratory and pioneer of the 'Internet of Things', he's someone who should know.

Beginning with the tale of how Mozart's working method was reimagined by biographers keen to set him on a pedestal, the book sets out to deconstruct the myth of genius by looking at the truth behind many inventions, discoveries and works of art.

With help from a vast cast of characters ranging from Nobel laureates to Dexty's Midnight Runners, Ashton shows how, more often than not, great breakthroughs stem not from a flash of inspiration, but from the more mundane business of identifying problems, lateral thinking, trial and error, teamwork and persistence. It's an inspiring vision of creativity that's littered with practical advice, and is a cracking read to boot.



GILES SPARROW is a science writer and author. His latest book is *Mars*



## The Utopia Experiment

Dylan Evans

Picador **H** £11.99

THIS IS A fun read – as well as a scary one. *The Utopia Experiment* describes one man's response to the threat of imminent climate change. Dylan Evans, a psychologist turned robotics researcher, saw serious trouble ahead and set out to study how people might survive in a post-apocalyptic world. He bought land in Scotland, invited volunteers to join him, and set about trying to live without the support of modern civilisation. He and his band of yurt-living, apocalypse-ready campers attempted to apply their skills and science to building shelters (badly), growing food (ineptly) and keeping warm (or not).

Was this a serious experiment, or just a personal – and disastrous – indulgence in post-apocalyptic living? Was Evans secretly longing for the end of life as we know it? Was he lured by the heroic idea of surviving against the odds, by being among the few to cope with climate chaos? Was he drawn by an imagined escape from the troubles and stresses of modern life? Draw your own conclusion as the experiment unfolds and madness overtakes him.

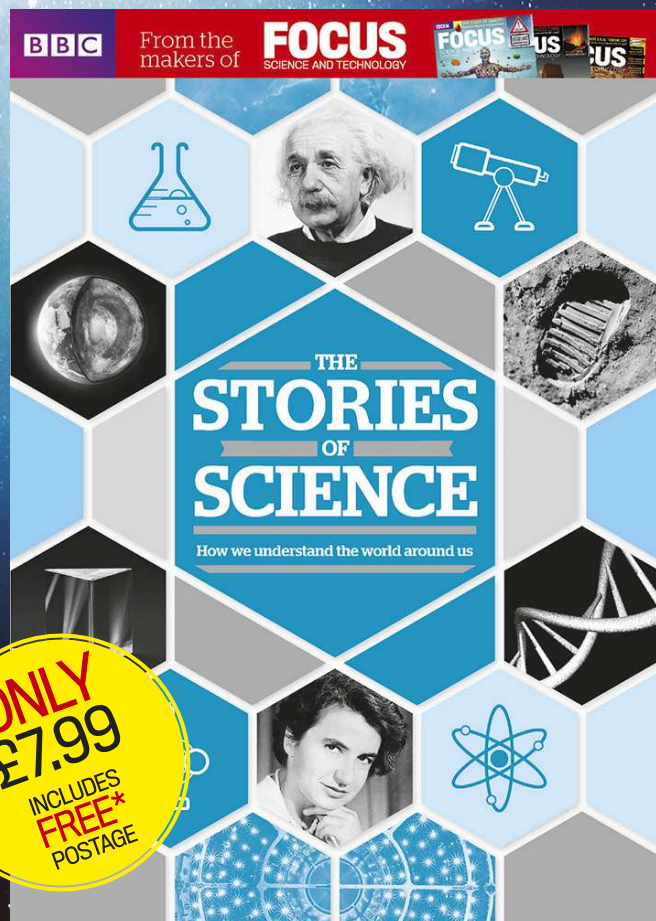


SUSAN BLACKMORE is a psychologist and a visiting professor at Plymouth University



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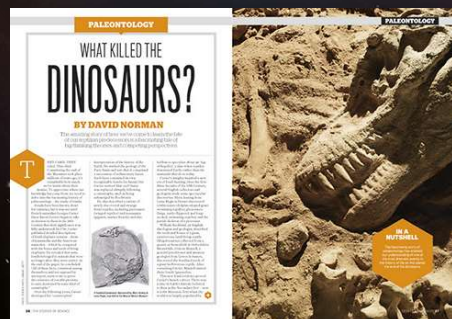
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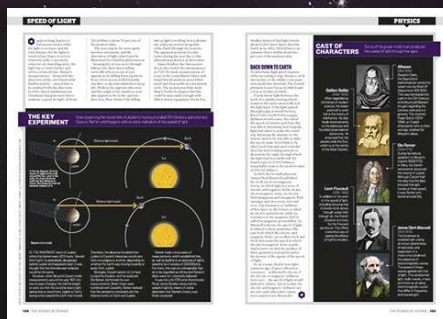
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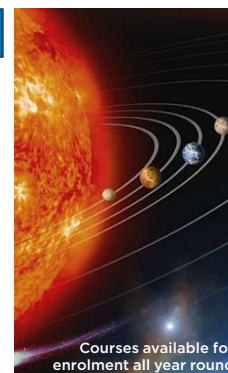
- GCSE Astronomy - for a certificate
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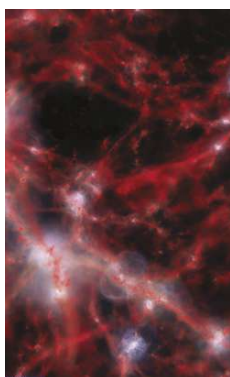
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MD15SP



# MINDGAMES

Test your knowledge with our Big Quiz set by **James Lloyd**

**1** Scientists created a computer program that they say is a perfect player of which game?

- a) Blackjack
- b) Poker
- c) Gin rummy

**2** Complete the recent headline: 'Regular \_\_\_\_ are key to learning'

- a) Snacks
- b) Naps
- c) Jogs

**3** January marked 10 years since an ESA probe landed on Saturn's moon, Titan. What was the probe's name?

- a) Huygens
- b) Herschel
- c) Hawking

**4** Which came top of SplashData's list of 2014's most popular passwords?

- a) password
- b) 123456
- c) qwerty

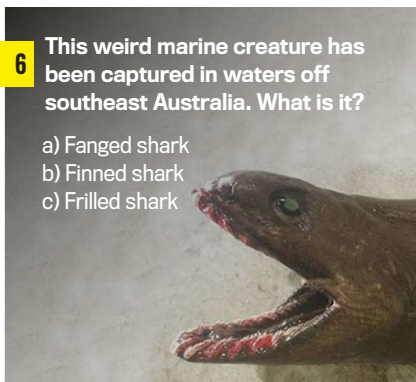
**5** To celebrate its 25th birthday, Hubble has revisited the iconic 'Pillars of Creation'. Where are they found?

- a) Crab Nebula
- b) Horsehead Nebula
- c) Eagle Nebula



**6** This weird marine creature has been captured in waters off southeast Australia. What is it?

- a) Fanged shark
- b) Finned shark
- c) Frilled shark



**7** Complete the recent headline: 'Computers judge \_\_\_\_ better than friends'

- a) Personality
- b) Intelligence
- c) Fitness

**8** Astronauts were recently evacuated from a US segment of the International Space Station after a suspected leak of what substance?

- a) Carbon monoxide
- b) Methane
- c) Ammonia

**9** Tracking devices have revealed the world's highest bird migration. Which bird makes the journey, reaching heights exceeding 7,000m?

- a) Pied wheatears
- b) Arctic terns
- c) Bar-headed geese

**10** Researchers in the US have built a microwave laser ('maser') that's the same size as what?

- a) A grain of rice
- b) A golf ball
- c) A dust mite

**11** What kind of animal is Tilda, recently filmed mimicking human speech in a bid to communicate with her keepers?

- a) Dolphin
- b) Orangutan
- c) Raven

**12** Researchers at the University of Surrey have found that doing what can help you to recall memories?

- a) Clenching your fists
- b) Holding your breath
- c) Closing your eyes

**13** Which British soprano recently began training for a trip to the International Space Station?

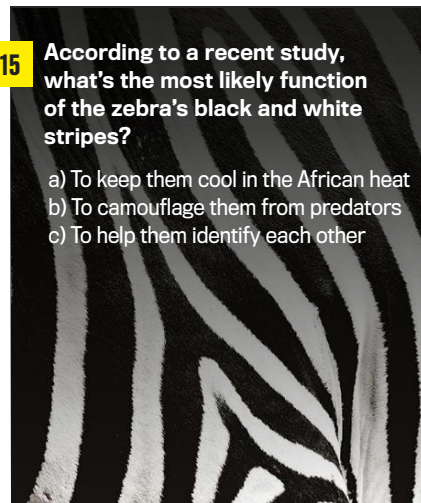
- a) Lesley Garrett
- b) Sarah Brightman
- c) Charlotte Church

**14** In January, the missing Beagle 2 was finally found on the surface of Mars. When did it initially land on the Red Planet?

- a) December 1998
- b) December 2003
- c) December 2008

**15** According to a recent study, what's the most likely function of the zebra's black and white stripes?

- a) To keep them cool in the African heat
- b) To camouflage them from predators
- c) To help them identify each other



## More puzzles online



Try solving puzzles from the BBC quiz *Only Connect* hosted by Victoria Coren Mitchell at <http://bbc.in/1vCOzuY>



## QUIZ ANSWERS

## HOW DID YOU SCORE?

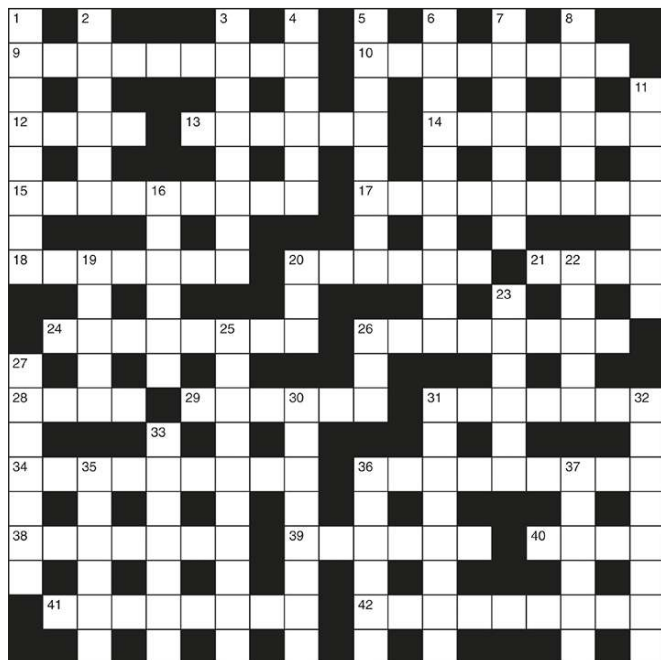
0-5 ASS

6-10 HORSE

11-15 ZEBRA

1b, 2b, 3a, 4b, 5c, 6c, 7a, 8c, 9c, 10a, 11b, 12c, 13b, 14b, 15a

## FOCUS CROSSWORD No 175



### ACROSS

- 9 Calcium oxide isn't slow to reach fruit (9)  
 10 Labyrinth that's within hearing (5,3)  
 12 The pain of bachelordom (4)  
 13 Freezing an ocean (6)  
 14 It's very important that it's extinct (7)  
 15 Tense, seen running in a state (9)  
 17 Sell off what's left (9)  
 18 Headless insects had vitamin D deficiency (7)  
 20 Part of the mouth that generates taste (6)  
 21 Spots cane construction (4)  
 24 Served report that was biased (8)  
 26 All pearl layouts are like the sides of a square (8)  
 28 Entrusted with oxidation (4)  
 29 Shudder in great remorse (6)  
 31 Fight club to get carving material (7)  
 34 Tree has until a change is made (9)  
 36 My tribute formed an element (9)  
 38 Way of restarting play worth using at home (5-2)  
 39 Group of alcoholics has arms sent into capital (6)  
 40 Only on the German river (4)  
 41 Former Chancellor to bar recipe with one cabbage (8)  
 42 Instrument to fix one's glass (4,5)

### DOWN

- 1 Illegal tenant is more dumpy (8)  
 2 Organism made meandering line around church (6)  
 3 Diseased? If so, ribs show abnormal formation (8)  
 4 One insect let off another (8)  
 5 Woman clears out - it's intuitive (8)  
 6 Mean to move terribly remote gauge (10)  
 7 Force Merlin to turn into a troublemaker (7)  
 8 Georgia performed with old fish (6)  
 11 Hire a treaty (7)  
 16 Variable, pursuing green form of power (6)  
 19 Plant credit note on ship (5)  
 20 Case of pressure getting too much (3)  
 22 Firm about communist beliefs (5)  
 23 Gold cord starts to provide muscle (6)  
 25 Ran her tiny form into the sea (10)  
 26 Same level within department (3)  
 27 Money gives the missing ending dimension (7)  
 30 Drug claims to work with another, to a point (8)  
 31 Supporter of nanny goat? (8)  
 32 Town that pours mud over chips (8)  
 33 Smart alec finds king lacking defence (4-3)  
 35 Cook lord an alternative form of bacon (6)  
 36 Foreign enemy managed to reach island (6)  
 37 One mind altered with uranium or another metal (6)

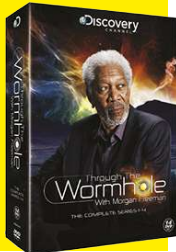
## SOLUTION TO CROSSWORD No 172

Trudi Needham, Michael Moran, Charles Caldwell, A McMinn and Frank Bryant each solved issue 276's puzzle and receive *The David Attenborough Collection* (Sky, £50).



## WIN! THROUGH THE WORMHOLE WITH MORGAN FREEMAN

The first five correct solutions drawn will each win a copy of *Through The Wormhole With Morgan Freeman* (Discovery, £39.99). Entries must be received by 5pm on 2 April 2015. See below for more details.



## YOUR DETAILS

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Post entries to *BBC Focus Magazine*, April 2015 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to [april2015@focuscomps.co.uk](mailto:april2015@focuscomps.co.uk) by 5pm on 2 April 2015. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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Read more about the Immediate Privacy Policy at [www.immediatemedias.co.uk/privacy-policy](http://www.immediatemedias.co.uk/privacy-policy). The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.



# HOLLYWOOD SCIENCE

## Conscious robots in Chappie

HOLLYWOOD LOVES A sentient robot. R2-D2, Johnny Five, WALL-E and Optimus Prime are often more animated than the characters they play alongside. This month meet new 'bot on the block, Chappie, in Neill Blomkamp's sci-fi comedy of the same name. Chappie, who looks like the Iron Giant with bunny ears, can think and feel for himself. But how close are we to making a conscious computer?

"No one has made a conscious robot yet," says computer scientist Prof Peter McOwan from Queen Mary, University of London. "But with enough understanding of human consciousness, hard work and investment, it could possibly be done."

The first hurdle is to define consciousness. This has been flummoxing us for centuries. The truth is, it's far easier to define unconsciousness than its more elusive antonym. Consciousness is embedded in a complex matrix of neural circuits, but we don't know how this

## "What's the point of having a hammer that worries about its hammer-y-ness?"

translates into thought or self-awareness. With a definition in the bag, the next step would be to somehow model consciousness and then design the circuitry needed to generate it. Consciousness would then need to be measured, which is difficult to do. "There are a few projects going on in the world with varying degrees of success," McOwan says. Some believe that generating human-like consciousness will depend on having a human-like body, so a long-legged Chappie may prove more self-aware than 2001: A Space Odyssey's disembodied HAL 9000.

It'll also be important to build in social intelligence. McOwan has helped design a robot that can recognise and respond to emotion. The robot, iCat, is a chess-playing moggy that gauges the gaze, facial expression and body posture of an opponent. It responds by making appropriate expressions and remarks back. An empathic cat – there's a first. Kids

build up a real social relationship with the kitty and McOwan's hope is that responsive computers of this kind may find a place in education – as long as they don't start bringing decapitated robot birds into the classroom.

But why would we want to build a conscious robot? Some argue that building one would shed light on the nature of human consciousness, but I think that Hollywood is more interested in the idea than anyone else. It's worth thinking just how practical such a machine would be. "What's the point of having a hammer that worries about its hammer-y-ness?" says McOwan. It's a good point.

Remember Marvin the Paranoid Android? Who'd wish existential angst on their DIY tools? Not me. ■



**HELEN PILCHER** is a science writer and comedian. She tweets from @Helenpilcher1





# It takes two, baby - for true stereo 'wireless' sound.



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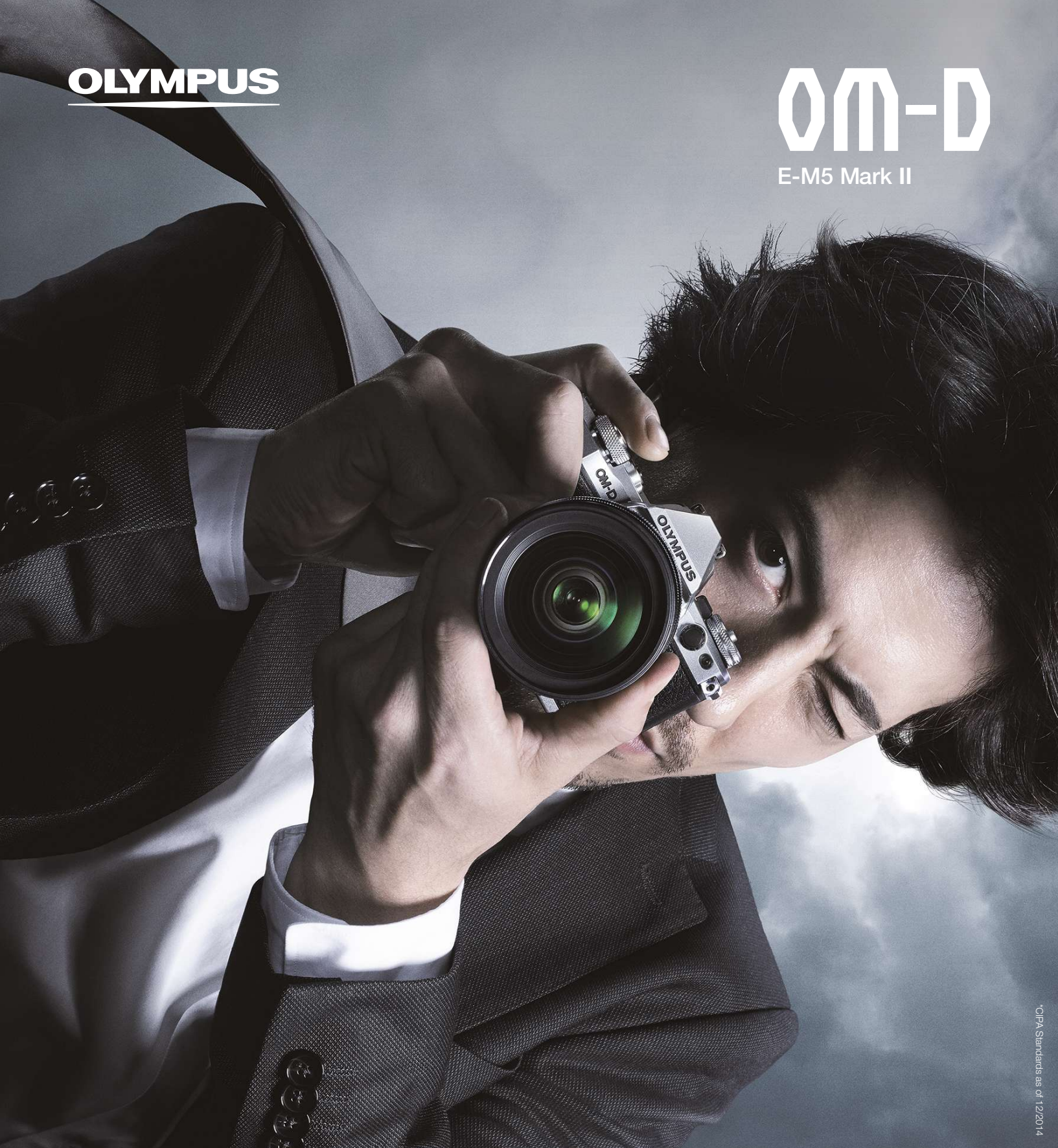
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